BLACKSTONE RIVER BASIN

MASSACHUSETTS, AND RHODE ISLAND

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MASTER MANUAL

OF

RESERVOIR REGULATION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

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P R E F A C E

The Blackstone River basin comprises an area of 478 square miles and is located in south-central Massachusetts and northern Rhode Island. The coordinated flood control plan for the basin, described in this manual, includes one dam and reservoir and four local protection projects.

This Master Regulation Manual includes a description of the basin, statistical, climatological and flood data, project descriptions and design criteria, regulation procedures for the flood control projects, and the effectiveness of the projects on the flood of record. The reservoir regulation portion of the manual for West Hill dam is contained in Appendix A. Appendix B contains operational procedures and maintenance of hydrologic equipment at the dam.

MANUAL OF RESERVOIR REGULATION
BLACKSTONE RIVER BASIN
MASSACHUSETTS AND RHODE ISLAND

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INTRODUCTION

1. BACKGROUND

The flood history of the Blackstone River basin extends back more than 140 years. Records concerning the early floods, although meager in most cases, mention "great" floods of 1818, 1876, 1877, 1886 and 1887. The most recent major flood events occurred in March 1936, July 1938 and August 1955. Despite earlier floods of the 1800's, a report dated 1929 (House Document No. 50, 71st Congress) concluded that improvement of the Blackstone River for power development, flood control or irrigation was neither practicable nor economically sound.

In 1940 a report on survey (House Document No. 624, 78th Congress) was prepared which included new flood data obtained from the 1936 and 1938 floods. The report presents results of an investigation of the Blackstone River and its tributaries for flood control with collateral studies on pollution, additional power and conservation storage, recreation, and sanctuary for wildlife. Flood control projects recommended and subsequently authorized included a flood control reservoir at West Hill on the West River in Massachusetts, a diversion conduit and channel from Kettle Brook to the Blackstone River bypassing the city of Worcester, Massachusetts and local protection improvements at Woonsocket and Pawtucket, Rhode Island. An interim review report on the Blackstone River basin (Lower Woonsocket, Rhode Island) dated 1957 and printed in House Document No. 87, 85th Congress recommends modification of the existing project for flood control in the Blackstone River basin to provide for local protection downstream from the existing project in Woonsocket, Rhode Island.

Subsequent to the August 1955 record flood which caused nearly $68 million in damages, construction funds were provided for the above mentioned projects with the exception of the Pawtucket local protection project which is currently in an "inactive" status. Pertinent information of the constructed projects are contained in table 1.

TABLE 1

PERTINENT PROJECT INFORMATION

Project	Date of Construction	Project Cost	August 1955 Flood, Recurring Damages Prevented
West Hill			
Dam & Reservoir	1959-1961	$2,300,000	$12.0 million
Worcester			
Diversion Project	1957-1960	$5,990,000	$25.4 million
Woonsocket			
Local Protection	1956-1960	$4,270,000	$ 8.6 million
Lower Woonsocket			
Local Protection	1963-1966	$9,150,000	$ 6.8 million

AUTHORIZATION AND SCOPE

2. AUTHORITY

This report is submitted pursuant to authority contained in ER 1110-2-240, dated 25 March 1963 (Reservoir Regulation) which requires that manuals of reservoir regulation for flood control, navigation or multiple-purpose reservoirs be prepared whenever storage allocated to one or more of the functions is the responsibility of the Corps of Engineers.

3. PURPOSE AND SCOPE

This manual will serve as a guide and reference source for higher authority, reservoir regulation and maintenance personnel in the New England Division office, respective flood control dam operators, and for other personnel who may become concerned with or responsible for regulation of the reservoir in the Blackstone River basin. Included in the manual are:

a. A concise history of events which led to the authorization of the Blackstone River basin projects.

b. A general description of the basin and major tributaries, including topographic features and statistical data relative to population, industry and agriculture.

c. Hydrometeorological data for the basin which include temperature, precipitation, snowfall, snow cover, storms, streamflow and floods.

d. A description of the coordinated plan of development for the basin consisting of a flood control dam and local protection projects.

e. Procedures for regulating the Blackstone River protective works.

f. Examples showing the effect of regulation of the West Hill Dam and Reservoir on the maximum recorded flood and standard project flood.

HISTORY OF BLACKSTONE RIVER BASIN REPORTS

4. PUBLISHED REPORT

In addition to the reports cited in paragraph 1 (Background), flood control of the Blackstone River and its tributaries is considered in Part Two, Chapter XVII of "The Resources of the New England-New York Region," dated 1957 and printed in Senate Document No. 14, 85th Congress. It presented a coordinated plan for watershed development, conservation, and use of land, water and related resources of the region. The report was prepared by the New England-New York Inter-Agency Committee and submitted to the President of the United States by the Secretary of the Army on 27 April 1956.

GENERAL DESCRIPTION

5. BLACKSTONE RIVER BASIN

The Blackstone River basin, located in south-central Massachusetts and northern Rhode Island, is generally elongated in shape with a length of about 41 miles, average width of 12 miles, and a total drainage area of 478 square miles. The topography is generally hilly with higher elevations lying in the western portion, some of which are in excess of 1,300 feet msl. Because of short, steep tributaries in the upper reaches of the watershed and relatively longer ones in the lower reaches, there is a tendency for the tributary flows to synchronize with the crest on the main river. A general basin map of the Blackstone River is shown on plate 1.

6. BLACKSTONE RIVER

The Blackstone River originates at the junction of the Middle River and Mill Brook in the southern part of Worcester, Massachusetts and flows in a generally southeasterly direction for 44 miles to its mouth at the Main Street dam in Pawtucket, Rhode Island. From this point the river is known as the Seekonk River and becomes a tidal estuary. It flows south for 7 miles into the Providence River in Providence, Rhode Island. The Blackstone River has a total fall of about 440 feet from its source to sea level. From Worcester to Fisherville, a distance of approximately 10 miles, the river falls 150 feet or about 15 feet per mile. In the next 18 miles to Blackstone, Massachusetts the average fall is only about 5 feet per mile. The river valley in this reach is broad and flat and has a marked modifying effect on floods in the basin. Downstream of Blackstone, the river drops 75 feet in 3 miles, then flattens out to become a rather uniform slope of approximately 11 feet per mile to tidewater. A profile of the Blackstone River is shown on plates 2, 3 and 4.

During the 19th century, several small dams were constructed across the river to develop water power for industrial plants located along its banks. In recent years, a number of industrial plants have been abandoned. Those still remaining generally buy their electric power and use the dams to supply process water. Several dams on the Blackstone River and its tributaries were damaged during the August 1955 flood, and some of the peak stages experienced in the basin were the result of surges of water which were released when these dams failed.

7. TRIBUTARIES

a. General. The principal tributaries of the Blackstone River are Kettle Brook, Quinsigamond, Mumford, West, Branch and Mill Rivers. In the headwaters of the main river the largest single tributary is Kettle Brook which has its origin about 7 miles northwest of the city of Worcester. Kettle Brook terminates at Curtis Pond where Tatnuck and Beaver Brooks join it to form the Middle River, which in turn is joined by Mill Brook to form the Blackstone River.

b. Kettle Brook. Kettle Brook has its source near Paxton Center in the town of Paxton and follows a general southeasterly course to Stoneville where it turns in a northeasterly direction before entering Leesville Pond. From there it flows northwesterly into Curtis Pond, which curves easterly almost 180 degrees to join Beaver Brook and create the Middle River. In its 13 mile length, Kettle Brook falls approximately 650 feet. A large percentage of the total drainage area of 34 square miles is controlled by natural lakes and water supply reservoirs. In addition, the American Steel & Wire Company owns several reservoirs in the headwaters which are maintained for the purpose of conserving water to augment low-water flows at their plants downstream. A U. S. Geological Survey gaging station, with a drainage area of 31.3 square miles, is located on Kettle Brook between Leesville and Curtis Ponds. The Worcester Diversion Local Protection Project, completed in 1960, diverts high floodflows in Kettle Brook away from the city of Worcester.

c. Quinsigamond River. The Quinsigamond River basin has a drainage area of 35 square miles, a length of about 12 miles and a maximum width of 4.5 miles. It has many high hills and numerous lakes and ponds. The largest body of water is the 5-mile-long Lake Quinsigamond, located in the headwaters of the watershed, with a water surface area of about 1 square mile. This lake and the ponds downstream, coupled with the flat slope of the Quinsigamond River, have a decided effect on the time and peak of floodflows at the mouth of the river. From the outlet of Lake Quinsigamond the river falls approximately 65 feet in its 5-mile lenth, joining the Blackstone River at Fisherville.

d. Mumford River. The Mumford River flows from the outlet of Manchaug Pond in Sutton, Massachusetts, follows a meandering course in a general easterly direction to its mouth at Uxbridge, Massachusetts. In its 13-mile course the river drops approximately 300 feet from its source to its confluence with the Blackstone River. The basin has a drainage area of 58 square miles. Several large ponds and lakes in the headwaters provide considerable natural storage. In addition, many small dams and reservoirs developed by textile and machinery industries help reduce and retard peak flood discharges in the basin.

e. West River. The West River basin, with a drainage area of 35 square miles, is elongated in shape with a length of about 12.5 miles and a width varying from about 5 miles in the upper portion to about 2 miles in the lower portion. The basin consists of low, rolling wooded hills and broad valleys with scattered lake and swamp areas. Elevations range from about 600 to 200 feet above mean sea level. The river has its origin at Silver Lake in the northwestern corner of the basin, approximately 2 miles southeast of the town of Grafton, Massachusetts. The West River flows in a general southeasterly direction from its source through West Upton, where it is joined by Warren Brook, then gradually turns to a more southerly course to its mouth about 1 mile south of Uxbridge, Massachusetts. The total length of the river is approximately 16 miles, during which it falls about 150 feet. The West Hill flood control dam, situated on the West River, reduces flood crests on the West and Blackstone Rivers.

f. Branch River. The Branch River, the largest tributary in the Blackstone River valley, has a drainage area of 96 square miles, of which 13 are in Massachusetts and 83 in Rhode Island. The basin is shaped somewhat like an inverted equilateral triangle, with each side approximately 15 miles long. The mouth of the river is at the northeast corner of the basin near the Massachusetts-Rhode Island state line, about 1½ miles north of the city of Woonsocket. The Branch River is formed by the confluence of the Pascoag and Chepachet Rivers near the town of Mapleville, Rhode Island and flows in a general northeasterly direction for 9 miles to its mouth. The Chepachet River drains the southern part of the basin, whereas the Pascoag River and its principal tributary, the Clear River, carry the drainage from the northwestern section of the basin. Some of the higher hills are located in this area with elevations as high as 800 feet msl. Elevation of the Branch River at its mouth is about 200 feet msl. In spite of the hilly terrain, there are many lakes, ponds and artificial reservoirs in the basin which modify floodflows.

g. Mill River. The Mill River has its source at North Pond in Milford, Massachusetts and flows in a southerly direction to its confluence with the Blackstone River at Woonsocket. In its 18-mile length, Mill River has a fall of about 230 feet of which 23 feet occur in its 1 mile reach within Woonsocket. The basin, which is about 16 miles long and 2 miles wide, has a drainage area of 34.7 square miles. The basin consists of low rolling wooded hills and broad valleys with scattered lake and swamp areas which have a large modifying effect on floods. Harris Pond, impounded by a dam with a head of 36 feet and located at the city limits on the Rhode Island-Massachusetts state line, failed during the record flood of August 1955 and destroyed all dams on the lower Mill River within the city of Woonsocket. Use of these dams for industrial water supply was largely discontinued before the August 1955 flood and they have not been replaced.

DEVELOPMENT IN THE BASIN

8. POPULATION

All or part of 30 towns and 2 cities in Massachusetts and 6 towns and 5 cities in Rhode Island are within the Blackstone River basin. According to the 1960 U. S. Census, total population of the basin is approximately 892,000, an increase of 1 percent over the 1950 U. S. Census figure of 883,000.

	1950	1960	Percent Change
Massachusetts	394,907	432,663	+9.5
Rhode Island	487,726	459,325	-6.2
	882,633	891,988	+1.1

The Rhode Island and Massachusetts portions of the basin are mostly urban and suburban development. Most of the urban population is concentrated in the cities of Worcester and Attleboro, Massachusetts and Woonsocket, Central Falls and Pawtucket, Rhode Island. The suburban population is located mainly in the larger Massachusetts towns of Holden, Shrewsbury, Auburn, Grafton, Northbridge, Milford, Franklin and North Attleboro and Rhode Island towns of Lincoln and Cumberland.

9. INDUSTRY

Industry plays a predominant role in the economy of the Blackstone River basin. Thirty-seven percent of the population is engaged in industrial employment. Every community in the basin produces manufactured goods consisting mainly of metals, metal fabrication, machinery, jewelry, textiles, electrical machinery and components. The major portion of the industrial activity is located in the northerly and southerly sections of the basin in the cities of Worcester, Attleboro, Woonsocket, Central Falls and Pawtucket.

10. AGRICULTURE

Due to the population and industrial pressures, plus competition from other areas with better soil conditions, agricultural activity in the Blackstone River basin has declined to minor importance in recent years. The principal remaining agricultural pursuits are dairy, poultry, orchards, and truck farming which are conducted on scattered small farms. Less than 5 percent of the basin land area is utilized for agricultural purposes.

11. NATURAL RESOURCES

The natural resources of the Blackstone River basin are very few. The largest and most widely used resource is the river itself with its tributaries. Forests in the area are not commercially important at the present time, but their potential is being improved with forest management. The only mineral commodities being utilized in the basin are sand, gravel, granite and crushed stone which are available at several locations. Small copper and bog iron deposits have been worked in the past, but future production of these materials is unlikely. Deposits of quartz, meta-anthracite and limestone occur in the basin. Magnetite and ilmenite occur in quantity in Cumberland, Rhode Island. This material was previously used as iron ore, recently as crushed stone, and is a potential source of both titanium and iron.

HYDROLOGY

12. CLIMATOLOGY

a. General. The Blackstone River basin has a variable climate characterized by frequent but generally short periods of heavy precipitation in the summer and longer periods of less intense precipitation in the winter months. It lies in the path of the "prevailing westerlies" and cyclonic storms that move across the country from the west or southwest. The area is also exposed to coastal storms, locally known as "northeasters," that travel up the Atlantic seaboard. In addition, tropical hurricanes constitute an infrequent but very important potential for flood-producing precipitation, particularly from July to October. Thunderstorms may occur over the basin at any time of the year and may be of local origin or associated with a stationary front.

b. Temperature. The average annual temperature of the Blackstone River basin is about 49° F. Average monthly temperatures vary widely throughout the year, from between 25° F. and 30° F. in January and February to between 69° F. and 73° F. in July and August. Extremes in temperature range from occasional highs slightly in excess of 100° F. to infrequent lows in the minus "twenties," particularly in the northern portions of the basin. A record of temperatures has been maintained at Worcester, Massachusetts for the past 67 years and at Providence, Rhode Island for 56 years.

c. Precipitation. The mean annual precipitation over the basin is about 41 inches distributed rather uniformly throughout the year. Average monthly rainfalls at Providence range from a minimum of 2.28 inches in July to a maximum of 3.68 in August, and at Worcester from 3.16 inches in February to 4.00 in August. The range between maximum and minimum values of average rainfall does not exceed 2 inches at any station. Locations of precipitation stations are shown on plate 1.

d. Snowfall and snow cover. About one-third of the precipitation during the winter months is in the form of snow. Annual snowfall averages from 35 to 40 inches with extremes ranging from 30 inches in the southern portions to about 60 at inland points to the north. In recent years, surveys of snow cover have been taken regularly in the Blackstone River basin. The locations of snow courses are shown on plate 1. The mean annual water content of snow cover over the basin seldom exceeds 3 inches. On occasions, however, a maximum water content of more than 6 inches has been experienced in the upper Blackstone River basin. Moderately high springtime discharges frequently occur as the result of melting snow, but runoff from this source by itself has been insufficient during the period of record to cause a major flood. Serious flooding due to a combination of heavy rain and snowmelt, however, is a possibility nearly every year.

e. Storms. Three general types of storms occur in the Blackstone River basin: continental, coastal, and those associated with thunderstorms which may be of local origin or the result of a stationary front. Continental storms originate over the United States and southwestern Canada and move in a general easterly and northeasterly direction. These storms may be rapidly moving intense cyclones, or may be of the stationary type. They are not limited to any season or month but follow one another at more or less regular intervals with varying intensities throughout the year. Of the coastal storms, tropical hurricanes are the most important. They originate either near the Cape Verde Islands or in the Western Caribbean Sea and generally move in a westerly or northwesterly direction, recurving to the north as they near the mainland, and then to the northeast as they approach New England. Although the normal path is to the south and east of New England, they may be deflected over this area by continental cyclonic disturbances or by a large, slow-moving, anticyclonic center located northeast of New England. This latter phenomenon is known as a "blocking" high pressure cell. In general, hurricanes are likely to occur during the months of July through October with greater incidence of such storms in the months of August and September. Coastal storms of an extratropical nature differ from the aforementioned hurricanes principally in that they originate off the Carolina coastline. These coastal storms travel a path parallel to the coastline but further westward than that of hurricanes and cover a much greater area with precipitation. These storms occur most frequently during the autumn, winter and spring months. Thunderstorms may be of local origin or of the frontal type associated with the summer months.

13. STREAMFLOW

a. Discharge records. The U. S. Geological Survey publishes records of six stream gaging stations in the Blackstone River basin, four of which are on tributaries and two on the main stream. The tributary gages in Massachusetts are located on Kettle Brook at Worcester, the Quinsigamond River at North Grafton and the West River near Uxbridge, and in Rhode Island at the Branch River at Forestdale. On the main stream there are two gaging stations: one at Northbridge, Massachusetts which measures runoff from about 30 percent of the basin, and the other at Woonsocket, Rhode Island which measures runoff from about 85 percent of the basin. A gage on the Mumford River at East Douglas, Massachusetts was discontinued in 1951. Pertinent data on the existing gages are summarized in table 2. Stage-discharge tables for the USGS gaging stations presently in operation are shown on plates A-14 to A-19.

TABLE 2

BLACKSTONE RIVER BASIN
STREAMFLOW RECORDS THROUGH WATER YEAR 1962

Location of Gaging Station	Drainage Area (sq.mi.)	Period of Record	Mean (cfs)	Instantaneous Maximum (cfs)	Daily Minimum (cfs)
Kettle Brook at Worcester, Mass.	31.3	1923 -	54.0	3,970 (1)	0.2
Quinsigamond River at North Grafton, Mass.	25.5	1939 -	42.9	820 (1)	0.3
Blackstone River at Northbridge, Mass.	139.0	1939 -	246.0	16,900 (1)	2.0
West River below West Hill Dam near Uxbridge, Mass.	27.9	1962 - Records too short for discharge statistics			
Mumford River at East Douglas, Mass.	27.8	1939 - 1951	44.8	420 (2)	3.0
Branch River at Forestdale, R. I.	93.3	1940 -	166.0	5,800 (3)	5.2
Blackstone River at Woonsocket, R. I.	416.0	1929 -	731.0	32,900 (1)	21.0

(1) Occurred in August 1955 (observed)
(2) Occurred in August 1955 (estimated)
(3) Occurred in March 1936 (estimated)

b. Runoff. The average annual runoff from the Blackstone River for the period of record through September 1963, adjusted for upstream storage and diversion, is 246 cfs at Northbridge, Massachusetts and 731 cfs at Woonsocket, Rhode Island. At Worcester, Massachusetts the average annual runoff from Kettle Brook is 54 cfs for the 40 years of record. The maximum, minimum and mean monthly runoff for these three stations is given in table 3.

14. FLOODS OF RECORD

a. General. Outstanding floods on the Blackstone River may be expected to occur during any season of the year. Early spring rains combined with melting snow resulted in the flood of March 1936. Heavy rains during summer and fall months caused the floods of November 1927, July 1938, September 1954, October 1955 and the record flood of August 1955.

b. Historic floods. The flood history of the Blackstone River basin extends back more than 140 years. Records concerning the early floods, although meager in most cases, mention "great" floods of 1818, 1876, 1877, 1886 and 1887. The greatest of these occurred in February 1886 and far exceeded any previous one for which information was available.

c. Recent floods. Since November 1927, three more major floods have been experienced: March 1936, July 1938 and August 1955. Minor events have also occurred in September 1938, September 1954 and October 1955.

The March 1936 flood (plate 5) actually occurred as two peaks of almost equal magnitude six days apart. The first peak, slightly less than the second, was the result of a combination of rainfall and snowmelt. The second peak was caused by heavy rainfall which varied from 3 inches in the lower part of the basin to 7 inches in the upper part. In addition, the already saturated soil reduced the rate of infiltration and, therefore, contributed in producing runoff coefficients as high as 90 percent.

The flood of August 1955 (plate 6), the greatest of record on the Blackstone River, was nearly twice the magnitude of any previous peak discharge. The flood resulted from record rainfall accompanying hurricane "Diane" falling on ground previously saturated by the precipitation of hurricane "Connie" which occurred only a week earlier. Table 4 is a summary of the 5 highest floods recorded at the USGS gaging stations in the Blackstone River basin.

TABLE 3

MONTHLY RUNOFF (CFS)

Month	Kettle Brook at Worcester, Mass. (DA = 31.3 sq.mi.)			Blackstone River at Northbridge, Mass. (DA = 139 sq.mi.)			Blackstone River at Woonsocket, R. I. (DA = 416 sq.mi.)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	59	120	12	270	550	66	888	1,610	209
February	59	120	27	297	600	127	910	1,770	365
March	103	310	47	463	760	229	1490	4,060	732
April	105	230	34	489	920	206	1428	2,640	623
May	61	120	24	294	510	105	838	1,450	285
June	42	120	17	205	500	70	547	1,550	142
July	29	160	14	112	300	22	325	2,450	90
August	30	260	10	136	1,180	24	300	2,690	83
September	33	170	9	122	800	22	357	1,970	75
October	30	180	7	124	710	27	365	2,000	101
November	44	160	11	204	770	48	586	2,340	127
December	50	140	10	234	600	66	751	1,820	170
ANNUAL	54	90	24	246	390	135	731	1,140	324

TABLE 4

FLOODS OF RECORD
BLACKSTONE RIVER BASIN

USGS Gaging Station	Drainage Area (sq.mi.)	Peak Discharges Aug. 1955 (cfs)	July 1938 (cfs)	Mar. 1936 (cfs)	Sept. 1954 (cfs)	Sept. 1938 (cfs)
Kettle Brook, Worcester, Mass.	31.3	3,970	880	2,520	1,530	1,300
Quinsigamond River, North Grafton, Mass.	25.5	820	-	-	295	-
Blackstone River, Northbridge, Mass.	139.0	16,900	3,900(2)	7,500(2)	4,510	-
Branch River, Forestdale, R. I.	93.3	4,240	3,950	5,800(2)	3,080	-
Blackstone River, Woonsocket, R. I.	416.0	32,900(1)	15,100	15,000	9,400	6,000

(1) Affected by dam failure on Mill River. Flow without dam failure estimated to be 29,600 cfs.

(2) Gage not established at this time. Discharge value obtained by computation.

d. Flood profiles. High water profiles were determined from high watermarks and field surveys following the floods of March 1936 and August 1955. Flood profiles for the main river are shown on plates 2, 3 and 4.

e. Flood frequency. Peak discharge frequencies were computed in 1952 for all gaging stations and damage zones in New England. Following the August 1955 flood, basic data from the previous study were brought up-to-date and the frequency curves recomputed. The frequency analyses were made in accordance with procedures devised by Mr. L. R. Beard and described in Civil Works Engineering Bulletins 51-1 and 51-14. The initial applications to New England rivers are summarized in FCS Memorandum 52-General-3, "Flood Frequency Studies in New England." In the frequency studies initiated following the 1955 floods, mean and standard deviations were recomputed to include five additional years of flow data. Based on a regional analysis, a skew coefficient of 1.0 was adopted for the Blackstone River basin instead of a skew coefficient of 0.3 previously used. Discharge frequency data at the existing gaging stations in the Blackstone River basin are presented in table 5.

15. ANALYSES OF FLOODS

a. General. The floods of record in the Blackstone River basin were analyzed in detail to determine hydrologic development of the floods and flood potentialities of all tributaries and local areas, and the contribution of the tributaries and local areas at the various damage centers and index stations. Sufficient data were available from the floods of March 1936, July 1938, September 1954 and August 1955 for a hydrologic analyses of the Blackstone River basin.

b. Flood routing. The progressive average-lag method of flood routing was adopted for use in the Blackstone River basin because of its adaptability to component routing. The routing analyses were made according to procedures described in Engineering Manual EM 1110-2-1408 (1 March 1960). An empirical relationship was developed between inflow and outflow for each reach, allowance being made for distance of travel, storage in the reach, and relative timing of the flood peaks. The Blackstone River basin was divided into tributary watersheds and subareas for the flood analysis. The main river was divided into three reaches starting and ending at index points suitable for both hydraulic and economic analyses. Basin subareas and routing reaches are shown on plate 1.

TABLE 5

BLACKSTONE RIVER BASIN
NATURAL PEAK DISCHARGE FREQUENCY DATA
(Discharge in cfs)

Expected Probability Percent Chance	Years	Kettle Brook at Worcester, Massachusetts	Quinsigamond River at North Grafton, Mass.	Blackstone River at Northbridge Massachusetts	Branch River at Forestdale Rhode Island	Blackstone River at Woonsocket, Rhode Island
.50	200	4,730	1,570	16,200	7,250	30,600
1.00	100	3,430	1,190	11,950	5,830	23,900
2.0	50	2,460	890	8,750	4,660	18,700
4.0	25	1,800	680	6,590	3,780	14,900
5.0	20	1,590	610	5,820	3,840	13,500
10.0	10	1,120	450	4,190	2,750	10,400
20.0	5	800	330	2,940	2,150	7,800
50.0	2	500	195	1,750	1,500	5,200
60.0	1.67	450	175	1,600	1,420	4,800
70.0	1.44	410	160	1,500	1,350	4,500
80.0	1.25	380	153	1,400	1,300	4,200
90.0	1.13	350	150	1,300	1,290	3,900
95.0	1.06	335	149	1,250	1,285	3,700
99.0	1.02	315	143	1,200	1,275	3,500
99.9	1.+	300	136	1,150	1,270	3,250

c. Tributary contributions. Component hydrographs for each major tributary and local area were developed for the floods of record by a detailed analysis of all rainfall and streamflow data. Maximum use was made of stage-discharge records at USGS gaging stations and private dams. Component hydrographs then were routed downstream to determine their contributions to flood peaks at the control points. The March 1936 and August 1955 floods were analyzed to determine discharges that each tributary contributed to the flow at various damage centers and index stations. Results are shown in schematic form on plates 5 and 6. The top line of the graph represents the maximum flood peak as it progresses the entire length of the Blackstone River. The observed discharge values at the USGS gaging stations are shown at Worcester, Northbridge and Woonsocket. Discharge at intermediate points was determined by flood routing and by estimation of ungaged areas. A compilation of all major tributary and "local" contributions to peak discharges on the Blackstone River from Worcester, Massachusetts to Pawtucket, Rhode Island for the March 1936 and August 1955 floods are shown on tables 6 and 7, respectively.

16. STANDARD PROJECT FLOOD

a. General. The standard project flood for the Blackstone River basin is a flood that will be equalled or exceeded only on rare occasions. It was developed from standard project storm rainfall and unit hydrographs derived from analyzing floods of record. Separate hydrographs were developed for the principal tributaries and routed downstream in a manner similar to procedures followed in the investigations of the March 1936 and August 1955 floods.

b. Standard project storm rainfall. The standard project storm rainfall was based on criteria described in Civil Works Engineering Bulletin 52-8. It was assumed to be uniformly distributed over the entire watershed. The total storm rainfall, occurring in 48 hours, is 11.22 inches with a maximum 24-hour value of 9.65 inches and a maximum 6-hour value of 7.43 inches. Total losses from infiltration, surface detention, transpiration, and other tangible factors amounted to 3.14 inches during the 48-hour period of storm rainfall. Rates of precipitation, infiltration, and rainfall excess are listed in table 8.

TABLE 6

TRIBUTARY DISCHARGE CONTRIBUTIONS
MARCH 1936 FLOOD

Tributary	Drainage Area (sq.mi.)	Tributary Peak Discharges (cfs)	Discharge Contributions			
			Worcester (cfs)	Northbridge (cfs)	Woonsocket (cfs)	Pawtucket (cfs)
Kettle Brook	31	2,520	2,520	1,900	1,000	1,000
Tatnuck and Mill Brooks	30	2,420		1,900	1,000	1,000
Local Area (L-1)	43	3,230		2,700	1,700	1,700
Quinsigamond River	35	1,050		1,000	700	700
Northbridge (USGS Gage)	139			7,500		
Local Area (L-2a)	27	1,650			200	200
Mumford River	58	3,490			1,800	1,800
West River	35	1,420			700	700
Branch River	96	5,800			5,800	5,400
Local Area (L-2b)	14	860			100	100
Mill and Peters Rivers	47	2,800			2,000	1,900
Woonsocket (USGS Gage)	416				15,000	
Local Area (L-3)	37	2,000				1,500
Abbott Run	25	400				400
Pawtucket (Slater Mill Dam)	478					16,400

TABLE 7

TRIBUTARY DISCHARGE CONTRIBUTIONS
AUGUST 1955 FLOOD

Tributary	Drainage Area (sq.mi.)	Tributary Peak Discharges (cfs)	Discharge Contributions: Worcester (cfs)	Northbridge (cfs)	Woonsocket (cfs)	Pawtucket (cfs)
Kettle Brook	31	3,970	3,970	3,200	2,300	2,100
Tatnuck and Mill Brooks	30	4,000		3,200	2,300	2,100
Local Area (L-1)	43	7,500		7,500	3,200	3,000
Quinsigamond River	35	1,200		1,100	900	900
Northbridge (USGS Gage)	139			15,000		
Local Area (L-2a)	27	2,570			2,300	1,700
Mumford River	58	7,000			5,800	5,400
West River	35	6,000			4,400	3,900
Branch River	96	4,300			3,400	3,600
Local Area (L-2b)	14	1,340			1,200	900
Mill and Peters Rivers	47	4,900 (1)			3,800 (1)	3,900
Woonsocket (USGS Gage)	416				29,600 (1)	
Local Area (L-3)	37	4,700				1,600
Abbott Run	25	3,800				1,000
Pawtucket (Slater Mill Dam)	478					30,100

(1) Estimated flow assuming Harris Pond Dam had not failed

TABLE 8

STANDARD PROJECT STORM RAINFALL
BLACKSTONE RIVER BASIN

Time (hrs)	Rainfall (inches)	Infiltration (inches)	Rainfall Excess (inches)
0	0.00	0.00	0.00
6	7.43	0.60	6.83
12	1.16	0.60	0.56
18	0.68	0.60	0.08
24	0.38	0.38	0.00
30	1.21	0.60	0.61
36	0.19	0.19	0.00
42	0.11	0.11	0.00
48	0.06	0.06	0.00
TOTALS	11.22	3.14	8.08

c. Unit hydrographs. A review was made of the 5 recent major floods in the Blackstone River basin (March 1936, July 1938, September 1938, September 1954 and August 1955) for unit hydrograph analysis. The latter storm generally produced the most critical conditions of flow through the watershed. Separate 6-hour unit graphs, developed for each of the 8 tributaries and 3 uncontrolled local areas, are included on plate 7.

d. Standard project flood. The standard project flood hydrographs for the selected tributaries and local areas were derived by applying the standard project storm rainfall excess to the respective 6-hour unit graphs. Each component was then routed progressively to all downstream index points following the same method used for the floods of record. The resultant standard project flood peak discharge at Northbridge, Massachusetts was 20,900 cfs. A maximum discharge of 43,500 cfs would occur at Woonsocket, Rhode Island and 46,300 cfs at Pawtucket, Rhode Island. Total standard project flood hydrographs and components at Northbridge and Woonsocket are shown on plate 7.

FLOOD DAMAGES

17. GENERAL

The maximum flood of record on the Blackstone River basin occurred in August 1955. Over 80 percent of the damage caused by the August flood occurred along the main stem of the Blackstone River and on its headwater tributaries in Worcester, Massachusetts. Although flooding extended from the headwaters in and near Worcester to tidewater at Pawtucket, the heaviest damage within the basin was experienced in the middle and upper reaches of the Blackstone valley in an area delimited, in general, by the major damage centers of Worcester and Woonsocket.

The total loss of the August flood in the Blackstone River basin amounted to an estimated $65.4 million, representing 13 percent of the total damage sustained in the southern New England flood area. Of the total damage in the basin 57 percent occurred in Massachusetts, the remainder in Rhode Island. Almost three-quarters of the total damage in the basin occurred in two of the valley's most heavily industrialized centers: Worcester, Massachusetts and Woonsocket, Rhode Island. Losses by area and type are presented in table 9.

Stage vs. damage curves shown on plate 8 are intended to provide a quick estimate of flood damage for the Blackstone River basin. Additional detailed surveys following a flood event would supplement this data as required. Data from damage zones are correlated with stages at the index stations at the Webster Street bridge in Worcester, Massachusetts, USGS gage at Northbridge, Massachusetts and USGS gage at Woonsocket, Rhode Island.

FLOOD CONTROL PLAN

18. GENERAL

The coordinated flood control plan for the Blackstone River basin consists of one dam and reservoir on the West River and five local protection projects; one is located in Worcester and two in Woonsocket. A local protection project at Uxbridge, Massachusetts authorized by section 205 of the 1948 Flood Control Act is presently being designed.

TABLE 9

AUGUST 1955 FLOOD LOSSES
BLACKSTONE RIVER BASIN
(LOSS IN $1,000)

Area	Urban	Rural	Industrial	Utility	Highway	Railroad	Total
Massachusetts							
Worcester and Vicinity	$4,610	$ -	$20,900	$1,540	$1,730	$ 200	$28,980
Worcester to Mass.-R. I. Line	1,450	20	4,430	40	2,650	230	8,820
Subtotal	$6,060	$20	$25,330	$1,580	$4,380	$ 430	$37,800
Rhode Island							
Woonsocket and Vicinity	$5,750	$ -	$10,040	$ 470	$3,970	$1,180	$21,410
Woonsocket Area to Tidewater	1,060	-	4,450	40	350	310	6,210
Subtotal	$ 6,810	$ -	$14,490	$ 510	$4,320	$1,490	$27,620
Total	$12,870	$20	$39,820	$2,090	$8,700	$1,920	$65,420

The authorized Pawtucket local protection project is currently in an "inactive" status. Descriptions of the constructed flood control works are given in the following paragraphs and shown on plate 1. Pertinent data for West Hill Dam and Reservoir and the local protection projects are contained in tables 10 and 11, respectively.

19. WEST HILL DAM AND RESERVOIR

a. General. West Hill Dam and Reservoir, completed in 1960, is located in southeastern Massachusetts on the West River approximately 3.5 miles upstream of its junction with the Blackstone River. The dam site is located 14 miles southeast of Worcester, Massachusetts and 9 miles northwest of Woonsocket, Rhode Island. The reservoir has a flood control storage of 12,400 acre-feet, equivalent to 8.3 inches of runoff from the drainage area of 27.9 square miles. The relation of the dam and reservoir to other flood control projects in the Blackstone River basin is shown on plate 1. The master development plan of the reservoir is shown on plate 9. Major project components consist of: (a) an earth fill dam and 4 dikes, (b) an overflow ogee spillway section, and (c) a reservoir outlet through the spillway section of the dam (see plate 10). Several town roads have been raised or relocated for a total length of 2.5 miles.

b. Dam and dikes. The dam consists of a rolled earth fill embankment section 2,400 feet long with a maximum height of 48 feet. The top of dam is at elevation 282.0 feet msl, which provides for 12.8 feet of spillway surcharge and 5.2 feet of freeboard. The dam has a top width of 15 feet and side slopes at 1 on 2.5.

Dikes "A", "B", and "C" are also constructed of rolled earth fill with 15-foot top widths and 1 on 2.5 side slopes. The dike along the Wolf Hill Road alignment (dike "D") which serves as a public road, has a top width of 28 feet and side slopes at 1 on 2. Sections of the dam and dikes are shown on plate 11.

c. Spillway and outlet. The spillway and outlet works are located on the right abutment of the dam. The spillway has a concrete ogee weir, 50 feet in length with crest at elevation 264.0 feet msl. The outlet works through the spillway section of the dam, consisting of three gated 3'-0" x 5'-0" rectangular conduits, permit normal riverflows to pass and allow regulation of the reservoir during flood periods. For details see plate 12.

TABLE 10

PERTINENT DATA FOR WEST HILL FLOOD CONTROL DAM AND RESERVOIR

LOCATION	West River, Uxbridge, Massachusetts
DRAINAGE AREA (square miles)	27.9
RESERVOIR	
Flood Control Storage	
Capacity (acre-feet)	12,400
Inches Runoff	8.3
Area (spillway crest, acres)	1,025
DAM AND DIKES	
Type	Rolled earth fill
Length (feet)	2,400
Top Elevation (feet msl)	282.0
Maximum Height (feet)	48
Slopes	1 on 2.5
Top Width (feet)	15
Freeboard (above spillway design flood, ft.)	5.2
DIKES	
Type	Rolled earth fill
Length (feet)	1,200
Top Elevation (feet msl)	282.0
Maximum Height (feet)	19
Slopes	1 on 2.5
Top Width (feet)	15
SPILLWAY	
Type	Concrete overflow, uncontrolled
Length (feet)	50
Crest Elevation (feet msl)	264.0
Maximum Head (feet)	12.8
OUTLET WORKS	
Type	3 conduits through spillway section
Conduit Sizes	3'-0" x 5'-0"
Capacity (spillway crest, cfs)	1,480
Invert Elevation (feet msl)	234.0
Gate Type	Sluice
SPILLWAY DESIGN FLOOD	
Inflow (cfs)	26,000
Outflow (cfs)	8,900
Maximum Surcharge (feet)	12.8
Maximum Reservoir Elevation (feet msl)	276.8
PROJECT COST	$2,300,000
PLACED IN OPERATION	1961
MAINTAINED BY	NED

TABLE 11

PERTINENT DATA - LOCAL FLOOD PROTECTION PROJECTS

Project	Worcester Diversion Blackstone River Massachusetts	Woonsocket Blackstone River Rhode Island	Lower Woonsocket Blackstone River Rhode Island
Total Length of Dikes		1,310 feet	9,700 feet
Total Length of Concrete Walls		316 feet	Floodwall 1,480 feet T-Wall 685 feet
Number of Pumping Stations		1	2
Number, Type and Size of Pumps		2 - 20" Propeller	3 - 24" Propeller (Hamlet Dist.) 3 - 36" Propeller (Social Dist.)
Number and Type of Gates	2 - Sluice	2 - Sluice at pumping station 4 - Tainter at dam	
Number and Length of Pressure Conduits			Mill River 2 - 1,150 feet Peters River 1 - 1,180 feet
Total Length of Channels	11,300 feet	8,300 feet	3,250 feet
Miscellaneous	Tunnel 4,205 feet Dam 350 feet Spillway 180 feet		2 - Dam Demolition
Protection Provided	Reduce floodflows through the city of Worcester.	Protects Woonsocket upstream from South Main Street.	Protects the city of Woonsocket downstream of the South Main Street bridge. Standard project flood.
Date Started Date Completed	July 1957 Jan. 1960	July 1956 Jan. 1960	Dec. 1963 Mar. 1966 (Est)
Federal Cost When Built	$4,970,000	$4,055,000	$6,983,400
Maintained by:	City of Worcester	City of Woonsocket	City of Woonsocket
Corps of Engineers Damtender Inspection	Buffumville	West Hill	West Hill

d. Recreation. Principal recreational activities at West Hill Reservoir consist of picnicking, fishing and swimming. A natural depression on the West River within the reservoir was developed into a $1\frac{1}{2}$ acre swimming area. Reservoir areas designated for recreational use are shown on plate 9.

e. Design criterion. West Hill Dam is designed to withstand a spillway design flood with 6 inches of reservoir storage utilized at the beginning of the flood. The spillway design peak inflow is 26,000 cfs, equivalent to 930 csm from the 28 square mile drainage area. With spillway crest at elevation 264.0 feet msl and a spillway length of 50 feet, the maximum pool elevation reached 276.8 feet msl (12.8 feet surcharge) resulting in a peak spillway discharge of 8,900 cfs. The top of dam was set at elevation 282.0 feet msl providing 5.2 feet of freeboard. The spillway design flood is shown on plate 15.

f. Regulation procedures. The regulation procedures for West Hill Dam are contained in Appendix "A". There are no major deviations from the previously established SOP, dated May 1961.

g. Effectiveness of project. Hydrographs of the 1936, 1955 and SPF at Northbridge, Massachusetts and Woonsocket, Rhode Island are shown on plates 5, 6 and 7. Also shown is the effect of West Hill Dam and Reservoir on flood discharge at Woonsocket, the major downstream damage center on the Blackstone River. Plates 13 and 14 depict the 1955 and SPF at the reservoir. Table 12 summarizes the natural and modified discharge of the above mentioned floods at Woonsocket. With a recurrence of the record basin flood of August 1955, the project would prevent about $12 million of damages in downstream communities on the Blackstone River. The breakdown is as follows:

Urban	$5,240,000
Industrial	3,590,000
Utilities, highways, railroad and miscellaneous	3,170,000
Total	$12,000,000

TABLE 12

EFFECT OF RESERVOIR REGULATION
AT WOONSOCKET, RHODE ISLAND

Flood	Natural Flow (cfs)	Modified by West Hill Reservoir (cfs)
March 1936	15,140	14,550
August 1955	29,600	26,100
Standard Project Flood	43,500	40,000
Typical Tributary Contribution Flood	24,300	22,500

20. WORCESTER DIVERSION PROJECT

a. General. The Worcester Diversion, completed in 1960, is located in the towns of Auburn and Millbury, Worcester County, Massachusetts (see plates 16 and 17). Its intake is located in Auburn, approximately 1¼ miles south of Leesville dam on the easterly edge of Leesville pond, an artificial pond on Kettle Brook. From the intake, the diversion passes southeasterly in a tunnel through Pakachoag Hill, thence in an open channel following the general alignment of Hull Brook to the Blackstone River. The downstream portion of the return channel, which terminates about 3,500 feet south of the Worcester city limits, is in Millbury.

The function of the project is to divert floodflows originating in the Kettle Brook drainage area from the city of Worcester by a tunnel and channel to the Blackstone River below Worcester. Major project components necessary for this purpose consist of: (a) a control dam across Leesville pond; (b) an ungated overflow structure consisting of an intake weir and transition; (c) a concrete lined tunnel, partly in earth and partly in rock through Pakachoag Hill; (d) a stilling basin; and (e) a return channel cut partly in rock and partly in earth leading to the Blackstone River.

Gated outlets in the control dam spillway pass normal Kettle Brook flow without creating any diversion. Closure of the gated outlets will effect complete diversion of all flows up to the capacity of the tunnel. The following paragraphs contain a brief description of the project features and regulation. Details are contained in the Operation and Maintenance Manual dated October 1960.

b. Control dam. The control dam is located approximately $1\frac{1}{4}$ miles upstream from the outlet of the pond at Leesville dam. It consists of a concrete spillway 180 feet long and a nonoverflow earth dam 350 feet long with rock slopes. The concrete spillway section has a crest elevation of 492.0 feet msl. Two hand-operated 5' x 5' sluice gates are installed in the spillway adjacent to the right (easterly) bank. The nonoverflow structure is constructed of earth with an impervious core. Side slopes are protected with rock-fill 2'-0" thick.

c. Diversion structures. The diversion structure consists of an intake, concrete-lined tunnel, and a stilling basin at the tunnel outlet. The intake structure is a semi-circular weir with a crest elevation of 487.0 and forms the entrance to the 16-foot diameter tunnel, 4,205 feet long through Pakachoag Hill. Elevation of the tunnel invert and intake transition is 451.8 and the outlet portal is 407.0. The entire tunnel is circular in shape and lined with concrete. A stilling basin constructed of concrete in rock extends from the outlet portal 120 feet downstream with a concrete baffle installed in the rock channel 100 feet downstream from the end of the stilling basin.

d. Return channel. The return channel, extending from the end of the stilling basin to the Blackstone River, generally follows the bed of Hull Brook.

e. Design criteria. The diversion intake weir, with crest at elevation 487.0 and operating under a surcharge of 5 feet, will pass a flow of 6,000 cfs, which is the capacity of the diversion tunnel. This discharge is approximately 1.5 times the record flood of 3,970 cfs which occurred on 19 August 1955. For floods greater than 6,000 cfs, the excess will flow over the control dam spillway with crest at elevation 492.0, but the diversion will continue to handle its design capacity. The embankment section of the control dam has a top elevation of 498.0 which is 1 foot above the estimated water level if an additional 6,000 cfs is discharged over the control dam spillway.

f. Regulation procedures.

(1) General. Operation and maintenance of the flood control works are the responsibilities of the city of Worcester. Representatives of the New England Division, U. S. Army Corps of Engineers stand ready to advise the city in the operation of the project. There is no deviation from the previously established regulation procedure for the Worcester Diversion Project contained in the Operation and Maintenance Manual dated October 1960.

(2) Regulation - normal periods. The two 5'-0" x 5'-0" gates in the control dam spillway will remain wide open to permit passage of normal flows through Leesville pond.

(3) Regulation - flood periods.

(a) Rising stage. One gate may be closed whenever a severe storm has occurred, heavy spring runoff is taking place, or if high rates of flow are anticipated on tributaries of the Middle and Blackstone Rivers. Stages for operation of the gates and the regulation required are as follows:

STAGES FOR FLOOD CONTROL OPERATION

Index Location	Elevation (ft,msl)	Regulation Required
Gage at Webster Street Bridge	466.0	Close one gate
Gage at Webster Street Bridge	468.0	Close second gate

To assure full benefit from the project, premature closure of the control dam gates is preferable to a tardy operation.

(b) Falling stage. Following recession of the flood, when the stage at the index station falls to elevation 468.0 one gate may be opened and the second gate may be opened when the stage falls to elevation 466.0.

(4) Minimum flow. An 18-inch ungated outlet in the

control dam and local runoff generally supply the minimum flow of 18 cfs required by the Worcester Electric Company.

g. Effectiveness of project. With a recurrence of the record August 1955 flood (3,970 cfs), the project would prevent about $25.4 million of damages in Worcester as follows:

Urban	$ 2,390,000
Industrial	19,490,000
Utilities, highways, railroads and miscellaneous	3,520,000
Total	$25,400,000

21. UPPER WOONSOCKET LOCAL PROTECTION

a. General. The project (completed in 1960) is located in northeastern Rhode Island on the Blackstone River, and extends from South Main Street bridge in the center of the city of Woonsocket upstream for about 8,300 feet to the vicinity of the Massachusetts-Rhode Island state line. A small portion of the right bank above the Singleton Street bridge lies in the town of Smithfield, Rhode Island. A general plan of the project is shown on plate 18. Major project components consist of 8,300 feet of channel improvement including dikes and a floodwall, replacement of the Woonsocket Falls dam with a new dam, and a new pumping station. In addition, one highway bridge across the river was replaced as part of the project and three other highway bridges were constructed by local interests concurrently with the project. The following paragraphs contain a brief description of the project features and regulation. Details are contained in the Operation and Maintenance Manual dated October 1959.

b. Channel improvement. The channel improvement covers widening, deepening and straightening of about 8,300 feet of the Blackstone River, consisting of alterations to about 6,700 feet of channel and construction of about 1,600 feet of new channel. Bottom widths vary from 100 to 120 feet, except the approach to the dam has been flared to a bottom width of about 230 feet at the Woonsocket Falls dam. The channel bottom drops 0.183 percent in the upper 7,680 feet from elevation 144 to elevation 130 and then rises to elevation 132 as it approaches the dam.

c. Closure structure. There is one closure structure in the Woonsocket project located on River Street about 50 feet north of Singleton Street. The distance to be closed is 40 feet between the retaining walls at the ends of dikes 3 and 4. Height of the opening is about 4½ feet and will normally be closed with sandbags.

d. Woonsocket Falls dam. The Woonsocket Falls dam is a concrete structure having four 50-foot ogee weirs with 10.1 foot high tainter gates and a short nonoverflow right abutment section across an abandoned canal. The dam, founded on bedrock, is intended to pass rather than impound floodflows. Normal stream discharge flows over the tainter gates. The weir crest or gate sill is elevation 138.0 and the top of gates is elevation 148.1 (stage 0.0). The Woonsocket Falls dam is shown on plates 19 and 20.

e. Pumping station. The Singleton Street pumping station is located on the left bank below Singleton Street (see plate 18). The interior drainage system passing storm water through the pumping station drains about 31 acres in the Singleton area. During intense storms the system would also receive about half the runoff from 34 acres lying east of Harris Avenue. The station shown on plate 22 contains two 20-inch vertical propeller pumps, each with a capacity of 22 cfs against a head of 12 feet.

f. Design criteria. The Woonsocket Local Protection project was designed for a discharge of 30,000 cfs which is about 15 percent greater than the record flood of August 1955 (26,100 cfs).

g. Regulation procedures.

(1) General. Woonsocket Local Protection project is regulated by the city for protection of the city of Woonsocket and the town of North Smithfield, Rhode Island. The following paragraphs briefly describe regulation procedures of the project. Plate 18 presents the regulation schedule for Woonsocket Falls dam. A discharge rating curve for the dam is shown on plate 21. There are no deviations from the previously established regulation procedure for the Woonsocket project as contained in Operation and Maintenance Manual dated October 1959.

(2) Regulation - normal periods. When the 4 tainter gates of the dam are in a closed position, the water upstream of the dam will fluctuate above the gate crest (stage 0.0 feet) depending on the rate of flow in the river. No regulation is required for normal

riverflows below a stage of plus 2.5 feet, equivalent to about 1,800 cfs.

(3) Regulation - flood periods.

(a) Minor rise. Minor rises in river levels from flows 1,800 to 4,000 cfs generally occur annually and occasionally more than once in a year. Gate regulation will be required when river stage reaches +2.5 feet. Gate setting would vary from 0-0-0-0 (all gates closed) to 1-1-1-1 (all gates open 1 foot).

(b) Minor flood. A minor flood, with flows from 4,000 to 7,000 cfs, may be expected to occur every 2 to 3 years on the average. With a gate setting of 1-1-1-1 the pumping station operator would be alerted. As flow increases gate settings will increase from 1-1-1-1 to 2-2-2-2 to maintain a pool stage of about +2.5 feet.

(c) Major flood. A major flood with flows exceeding 7,000 cfs may be expected to occur once in 4 to 5 years. Gage settings above 2-2-2-2 will be determined by river stage at the pumping station. As soon as a stage of +4.0 is reached the pumping station operator will inform the dam operator. The dam operator will increase the gate setting to 2-2-2-3 and continue gate regulation as indicated on plate 18. When stage rises above +4.0 at the Singleton Street pumping station, the discharge gate will be closed and the station operated as required by local runoff conditions.

h. Effectiveness of project. The Woonsocket Local Protection project wil contain the design discharge of 30,000 cfs described in paragraph 21f - "Design Criteria." With a recurrence of the record flood (26,000 cfs in August 1955), the project would prevent about $8.6 million of damages in Woonsocket as follows:

Urban	$ 500,000
Industrial	6,300,000
Utilities, highways, railroads and miscellaneous	1,800,000
Total	$8,600,000

22. LOWER WOONSOCKET LOCAL PROTECTION PROJECT

a. General. The project presently under construction is located in the city of Woonsocket. The project shown on plate 23 consists of improvements to the Blackstone, Mill and Peters Rivers all within the city limits. Included in the protective works are channel improvement, dikes, floodwalls, conduits, pumping stations, removal of 2 dams, and construction of a small control dam. The following paragraphs contain a brief description of the project. Details of the projects will be contained in the Operation and Maintenance Manual presently under preparation.

b. Blackstone River. The local protection works on the Blackstone River consist mainly of channel improvement (400 feet) upstream of the Bernon dam, removal of the Bernon and Hamlet dams, construction of about 6,000 feet of dikes and floodwalls, and 2 new pumping stations at the locations shown on plate 23.

c. Mill River. The Mill River channel improvements extend from about 500 feet downstream of Privilege Street to its confluence with the Blackstone River, a total distance of 2,930 feet. The protective works consist of a small control dam and about 1,780 feet of channel improvement, including about 3,000 feet of dikes and floodwalls.

The Mill River flows from the improved open channel through a 1,150-foot, twin-barrelled pressure conduit to its confluence with the Blackstone River. Each conduit is generally rectangular in shape, 21 feet wide and 12 feet high with invert slopes at .001 and .0021. A section of the conduit is shown on plate 24.

d. Peters River. The improvement in the Peters River starts about 150 feet downstream of Mill Street with an 800-foot dike on the right bank and an improved open channel. The river then flows through an 1180-foot pressure conduit to the confluence of the Blackstone River. The improved channel has a 25-foot minimum bottom width with invert slope generally at $0.008\pm$. The 1180-foot pressure conduit which begins just upstream of Elm Street is 17 feet wide and 10 feet high with invert slopes varying from .0052 to .015. Sections of the conduit are shown on plate 25.

e. Pumping stations. The Lower Woonsocket protection project contains 2 pumping stations to discharge the interior runoff from the protected Hamlet and Social districts into the Blackstone River during high river stages.

The Hamlet district station (drainage area 185 acres) is located on the right bank of the Blackstone River about 300 feet downstream of the Hamlet Avenue bridge. The pumping station is equipped with three 24-inch propeller type pumps, each with a capacity of 28.0 cfs at a 15.4-foot head.

The Social district station (drainage area 284 acres) is located on the left bank of the Blackstone River at the confluence of the Mill and Peters Rivers. The pumping station is equipped with three 36-inch propeller type pumps, each with a capacity of 61.3 cfs at a 19.8-foot head.

f. Design criteria. The Lower Woonsocket Local Protection project was designed for the standard project flood as follows:

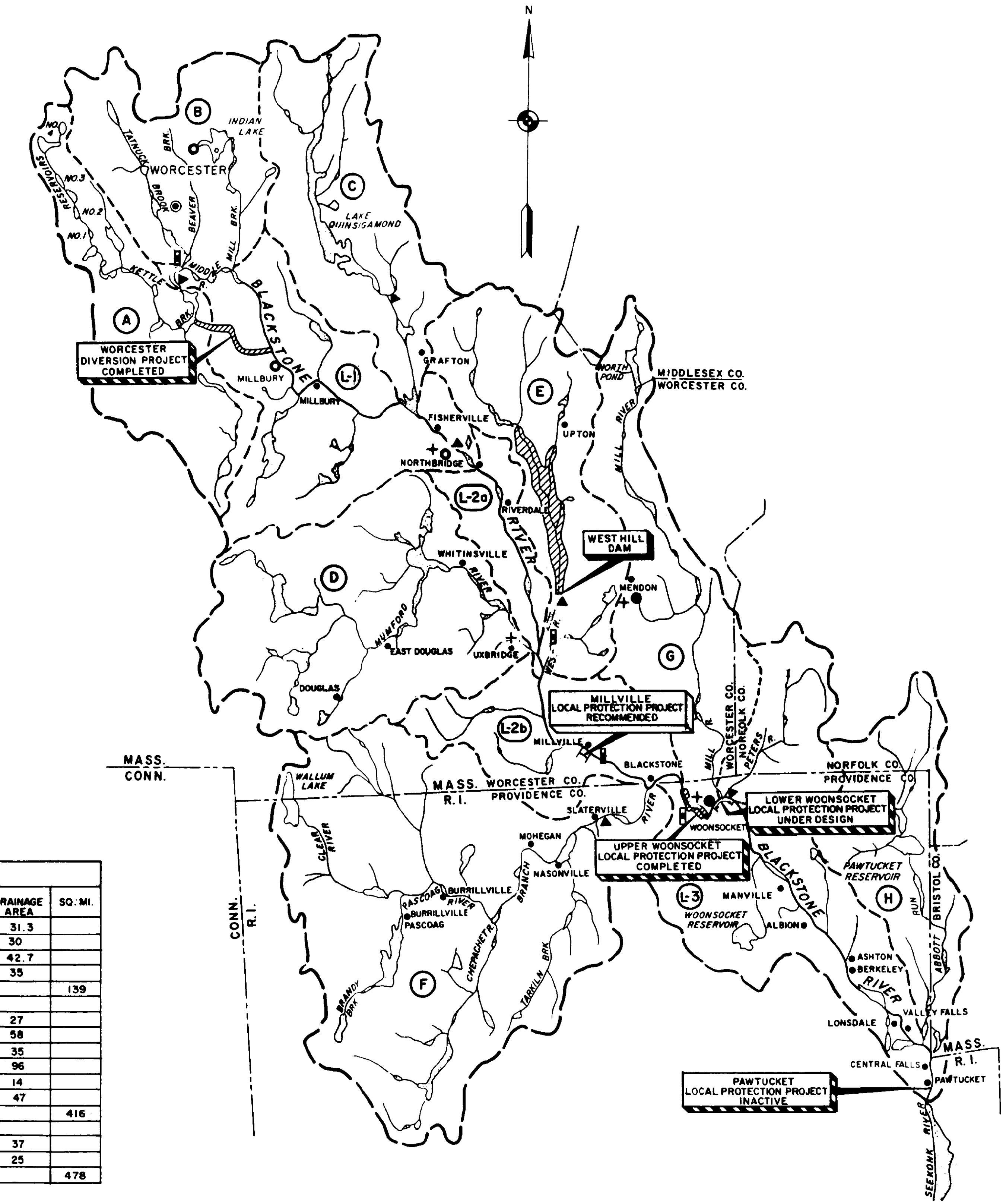
Blackstone River upstream of Mill and Peters Rivers	33,000 cfs*
Blackstone River downstream of Mill and Peters Rivers	40,000 cfs*
Mill River	8,500 cfs
Peters River	3,200 cfs

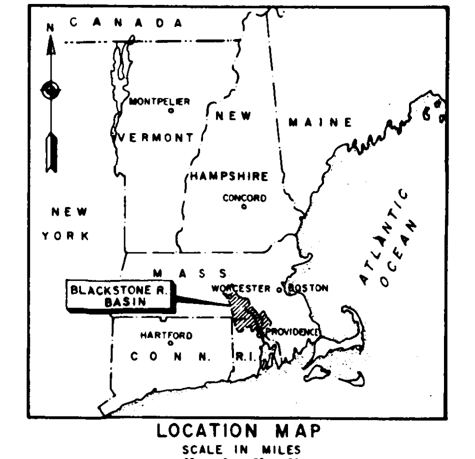
* Modified by West Hill Dam and Reservoir. SPF for lower Woonsocket is higher than SPF for upper Woonsocket because of revisions in storm distribution and unit hydrographs.

g. Regulation procedures. The effective regulation of the Lower Woonsocket Local Protection project is the responsibility of the city of Woonsocket. The only major items of the project requiring regulation are the pumping stations at the Hamlet and Social districts. A schedule for pumping requirements will be included in the Operation and Maintenance Manual prepared for the city.

h. Effectiveness of project. The Lower Woonsocket Local Protection project will contain the design discharges cited in paragraph 22f - "Design Criteria." With a recurrence of the record flood (August 1955), the project would prevent about $6.8 million of damages in lower Woonsocket as follows:

Urban	$ 400,000
Industrial	5,000,000
Utilities, highways, railroads and miscellaneous	1,400,000
Total	$6,800,000

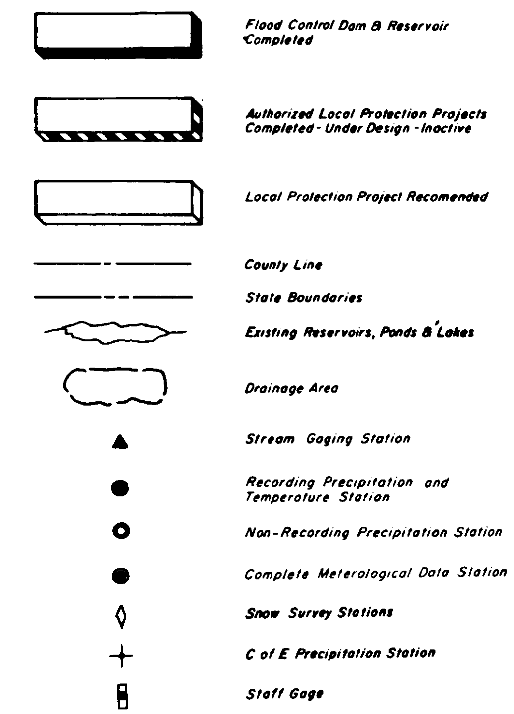




LOCATION MAP

SCALE IN MILES

25 0 25 50



AREAL SUB-DIVISIONS			
AREA	TRIBUTARY AREA	DRAINAGE AREA	SQ. MI.
A	KETTLE BROOK	31.3	
B	TATNUCK AND MILL BROOKS	30	
L-1	LOCAL-WORCESTER TO NORTHBRIDGE	42.7	
C	QUINSIGAMOND RIVER	35	
	BLACKSTONE RIVER AT NORTHBRIDGE		139
L-2a	LOCAL-NORTHBRIDGE TO BRANCH RIVER	27	
D	MUMFORD RIVER	58	
E	WEST RIVER	35	
F	BRANCH RIVER	96	
L-2b	LOCAL-BRANCH TO WOONSOCKET	14	
G	MILL AND PETERS RIVERS	47	
	BLACKSTONE RIVER AT WOONSOCKET		416
L-3	LOCAL-WOONSOCKET TO PAWTUCKET	37	
H	ABBOTT RUN	25	
	BLACKSTONE RIVER AT PAWTUCKET		478

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DR. BY | TR. BY | CK. BY

PROJECT ENGINEER

CHIEF, SECTION

SUBMITTED BY

CHIEF, PLANN & RPTS BRANCH

BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER BASIN

BASIN & VICINITY MAPS

BLACKSTONE RIVER MASS. & R.I.

APPROVED DATE

CHIEF ENGINEERING DIV.

SCALE

SPEC. NO CIV ENG -19-016-

DRAWING NUMBER

SHEET

PLATE NO. 1

CORPS OF ENGINEERS U. S. ARMY

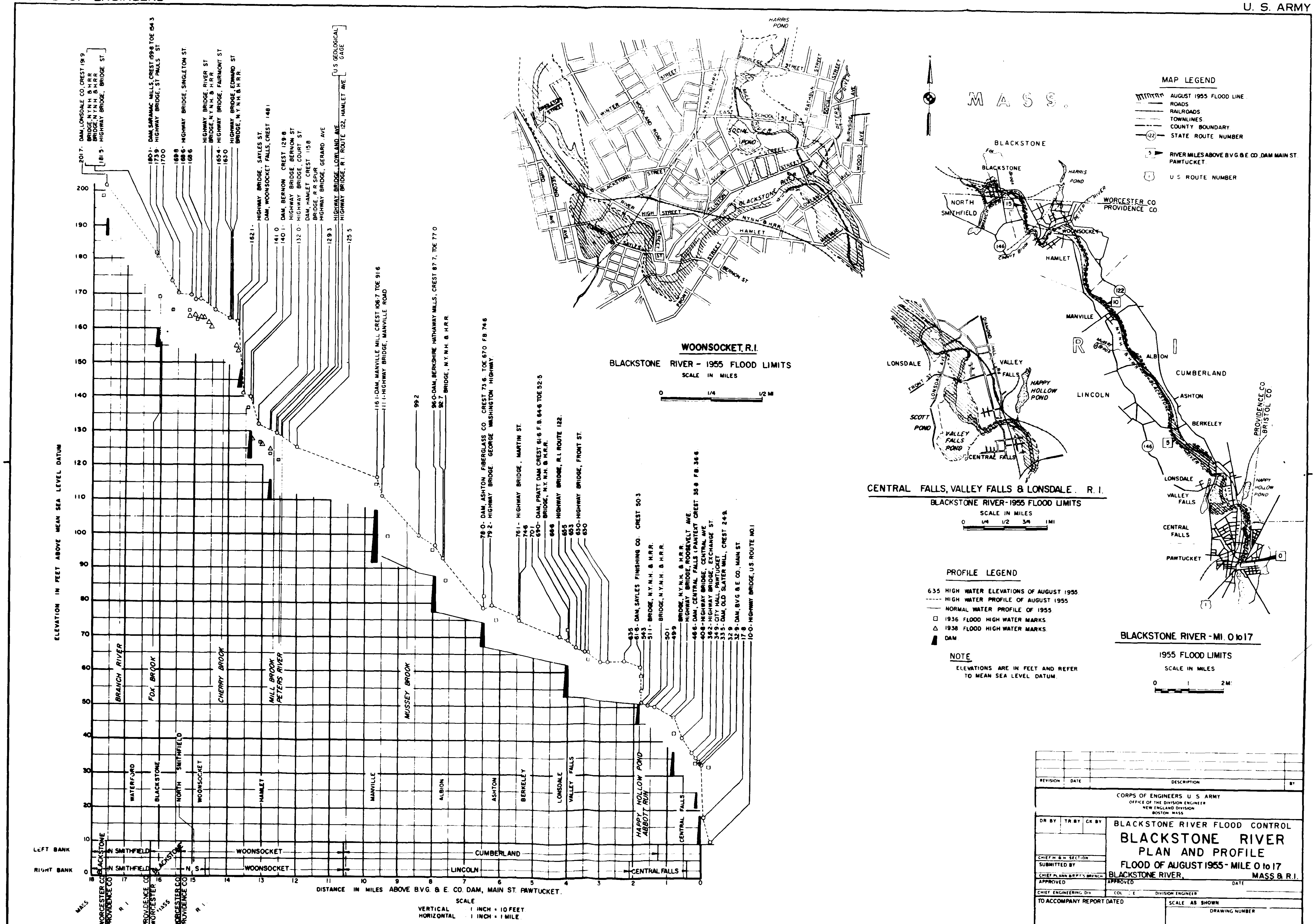
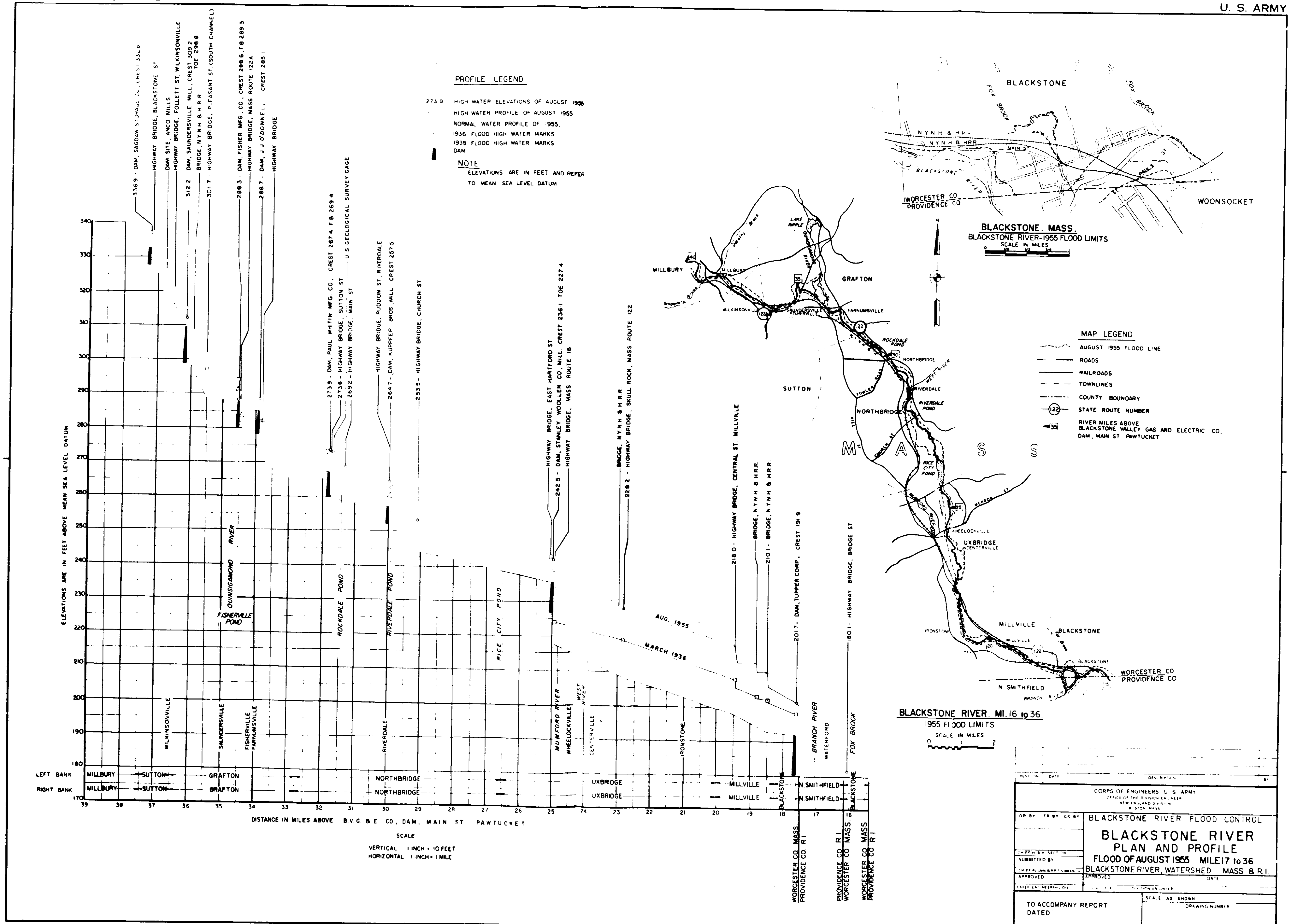
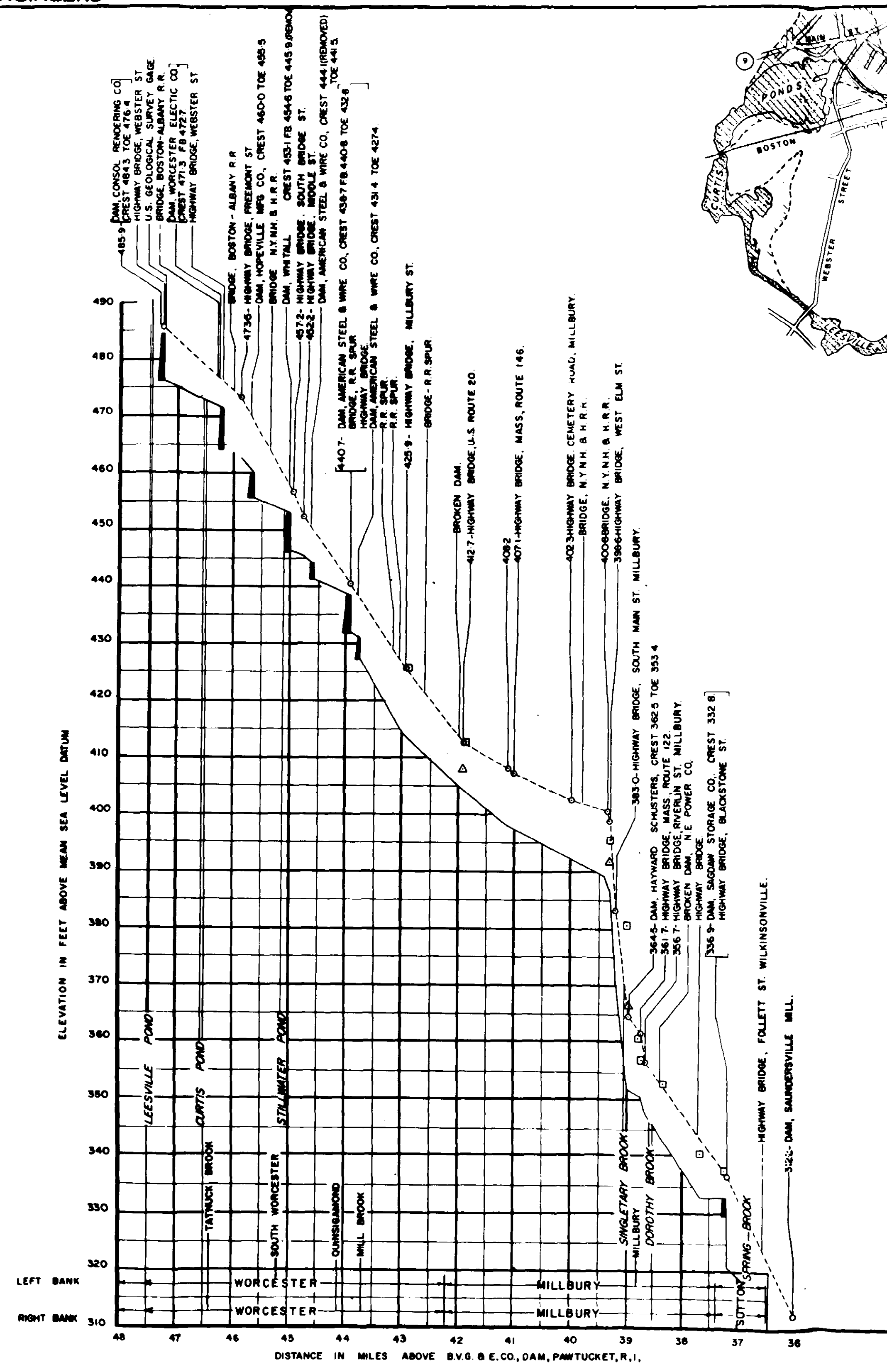


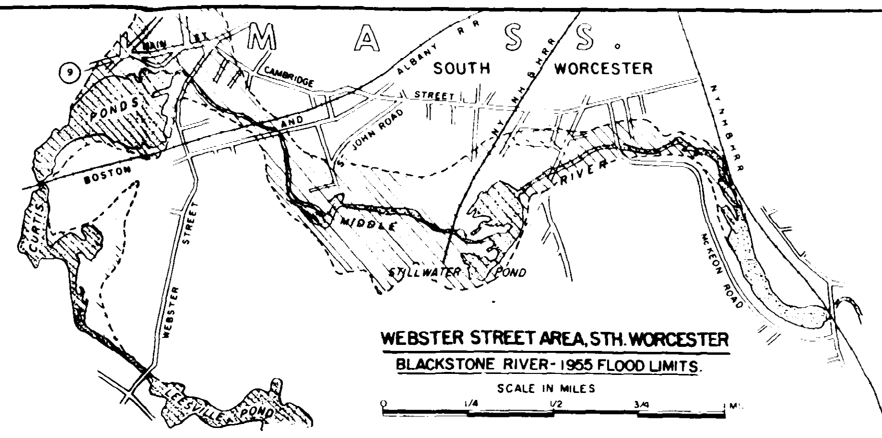
PLATE NO. 2


PROFILE LEGEND
273.0 HIGH WATER ELEVATIONS OF AUGUST 1955
HIGH WATER PROFILE OF AUGUST 1955
NORMAL WATER PROFILE OF 1955
1936 FLOOD HIGH WATER MARKS
1938 FLOOD HIGH WATER MARKS
DAM
NOTE
ELEVATIONS ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM
ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL DATUM
336.9 - DAM, SAGDAW STORAGE CO., CREST 335.6
HIGHWAY BRIDGE, BLACKSTONE ST
DAM SITE, ANCO MILLS
HIGHWAY BRIDGE, FOLLETT ST, WILKINSONVILLE
312.2 DAM, SAUNDERSVILLE MILL, CREST 309.2 TOE 298.8
BRIDGE, N.Y.N.H. & H.R.R.
301.7 - HIGHWAY BRIDGE, PLEASANT ST (SOUTH CHANNEL)
288.3 - DAM, FISHER MFG. CO., CREST 288.6, F.B. 289.3
HIGHWAY BRIDGE, MASS ROUTE 122A
288.7 - DAM, J. J. O'DONNEL, CREST 285.1
HIGHWAY BRIDGE
273.9 - DAM, PAUL WHITIN MFG CO, CREST 267.4 F.B. 269.4
273.8 - HIGHWAY BRIDGE, SUTTON ST
269.2 - HIGHWAY BRIDGE, MAIN ST
U.S. GEOLOGICAL SURVEY GAGE
HIGHWAY BRIDGE, PUDDON ST, RIVERDALE
264.7 - DAM, KUPFFER BROS., MILL CREST 257.5
253.5 - HIGHWAY BRIDGE, CHURCH ST
HIGHWAY BRIDGE, EAST HARTFORD ST
242.5 - DAM, STANLEY WOOLLEN CO., MILL CREST 236.1 TOE 227.4
HIGHWAY BRIDGE, MASS ROUTE 16
BRIDGE, N.Y.N.H. & H.R.R.
228.2 - HIGHWAY BRIDGE, SKULL ROCK, MASS ROUTE 122
218.0 - HIGHWAY BRIDGE, CENTRAL ST, MILLVILLE
BRIDGE, N.Y.N.H. & H.R.R.
210.1 - BRIDGE, N.Y.N.H. & H.R.R.
201.7 - DAM, TUPPER CORP., CREST 191.9
180.1 - HIGHWAY BRIDGE, BRIDGE ST
QUINSIGAMOND RIVER
FISHERVILLE POND
ROCKDALE POND
RIVERDALE POND
RICE CITY POND
MUMFORD RIVER
WEST RIVER
AUG. 1955
MARCH 1936
BRANCH RIVER
FOX BROOK
WILKINSONVILLE
SAUNDERSVILLE
FISHERVILLE
FARNUMSVILLE
RIVERDALE
WHEELOCKVILLE
CENTERVILLE
IRONSTONE
WATERFORD
LEFT BANK
RIGHT BANK
MILLBURY
SUTTON
GRAFTON
NORTHBRIDGE
UXBRIDGE
MILLVILLE
BLACKSTONE
N. SMITHFIELD
WORCESTER CO. MASS.
PROVIDENCE CO. R.I.
PROVIDENCE CO. R.I.
WORCESTER CO. MASS.
DISTANCE IN MILES ABOVE B.V.G. & E. CO., DAM, MAIN ST PAWTUCKET
SCALE
VERTICAL 1 INCH = 10 FEET
HORIZONTAL 1 INCH = 1 MILE
BLACKSTONE
FOX BROOK
N.Y.N.H. & H.R.R.
MAIN ST
BLACKSTONE RIVER
WORCESTER CO.
PROVIDENCE CO.
WOONSOCKET
BLACKSTONE, MASS.
BLACKSTONE RIVER-1955 FLOOD LIMITS
SCALE IN MILES
LAKE RIPPLE
MILLBURY
GRAFTON
WILKINSONVILLE
SAUNDERSVILLE
FISHERVILLE
FARNUMSVILLE
ROCKDALE POND
NORTHBRIDGE
WEST RIVER
RIVERDALE
RIVERDALE POND
SUTTON
RICE CITY POND
WHEELOCKVILLE
UXBRIDGE
CENTERVILLE
MILLVILLE
BLACKSTONE
IRONSTONE
WORCESTER CO
PROVIDENCE CO
N SMITHFIELD
M A S S
MAP LEGEND
AUGUST 1955 FLOOD LINE
ROADS
RAILROADS
TOWNLINES
COUNTY BOUNDARY
STATE ROUTE NUMBER
RIVER MILES ABOVE BLACKSTONE VALLEY GAS AND ELECTRIC CO. DAM, MAIN ST. PAWTUCKET
BLACKSTONE RIVER. MI. 16 to 36.
1955 FLOOD LIMITS
SCALE IN MILES
CORPS OF ENGINEERS U. S. ARMY
BLACKSTONE RIVER FLOOD CONTROL
BLACKSTONE RIVER
PLAN AND PROFILE
FLOOD OF AUGUST 1955 MILE 17 to 36
BLACKSTONE RIVER, WATERSHED MASS & R.I.
APPROVED
DATE
SCALE AS SHOWN
DRAWING NUMBER
TO ACCOMPANY REPORT
DATED



SCALE

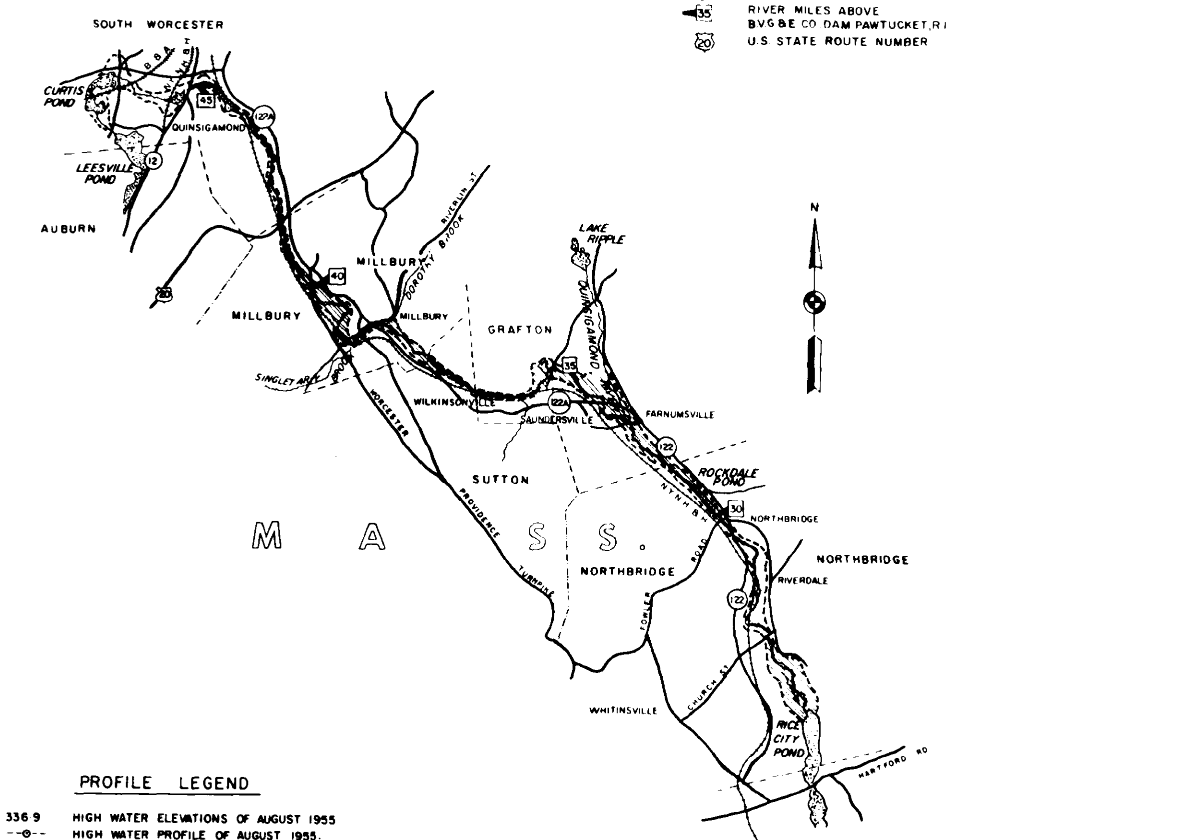
VERTICAL: 1 INCH = 10 FEET
HORIZONTAL: 1 INCH = 1 MILE



WEBSTER STREET AREA, STH. WORCESTER
BLACKSTONE RIVER - 1955 FLOOD LIMITS.
SCALE IN MILES

MAP LEGEND

- AUGUST 1955 FLOOD LINE
- ROADS
- RAILROADS
- TOWN LINES
- COUNTY BOUNDARY
- STATE ROUTE NUMBER
- RIVER MILES ABOVE B.V.G.& E. CO. DAM PAWTUCKET, R.I.
- U.S. STATE ROUTE NUMBER



PROFILE LEGEND

- 336.9 HIGH WATER ELEVATIONS OF AUGUST 1955
- HIGH WATER PROFILE OF AUGUST 1955.
- NORMAL WATER PROFILE OF 1955
- 1936 FLOOD HIGH WATER MARKS.
- 1938 FLOOD HIGH WATER MARKS.
- DAM

NOTE

ELEVATIONS ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

BLACKSTONE RIVER - ML 36 to 48

1955 FLOOD LIMITS

SCALE IN MILES

REVISION	DATE	DESCRIPTION

CORPS OF ENGINEERS U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR BY | TR BY | CK BY

BLACKSTONE RIVER FLOOD CONTROL

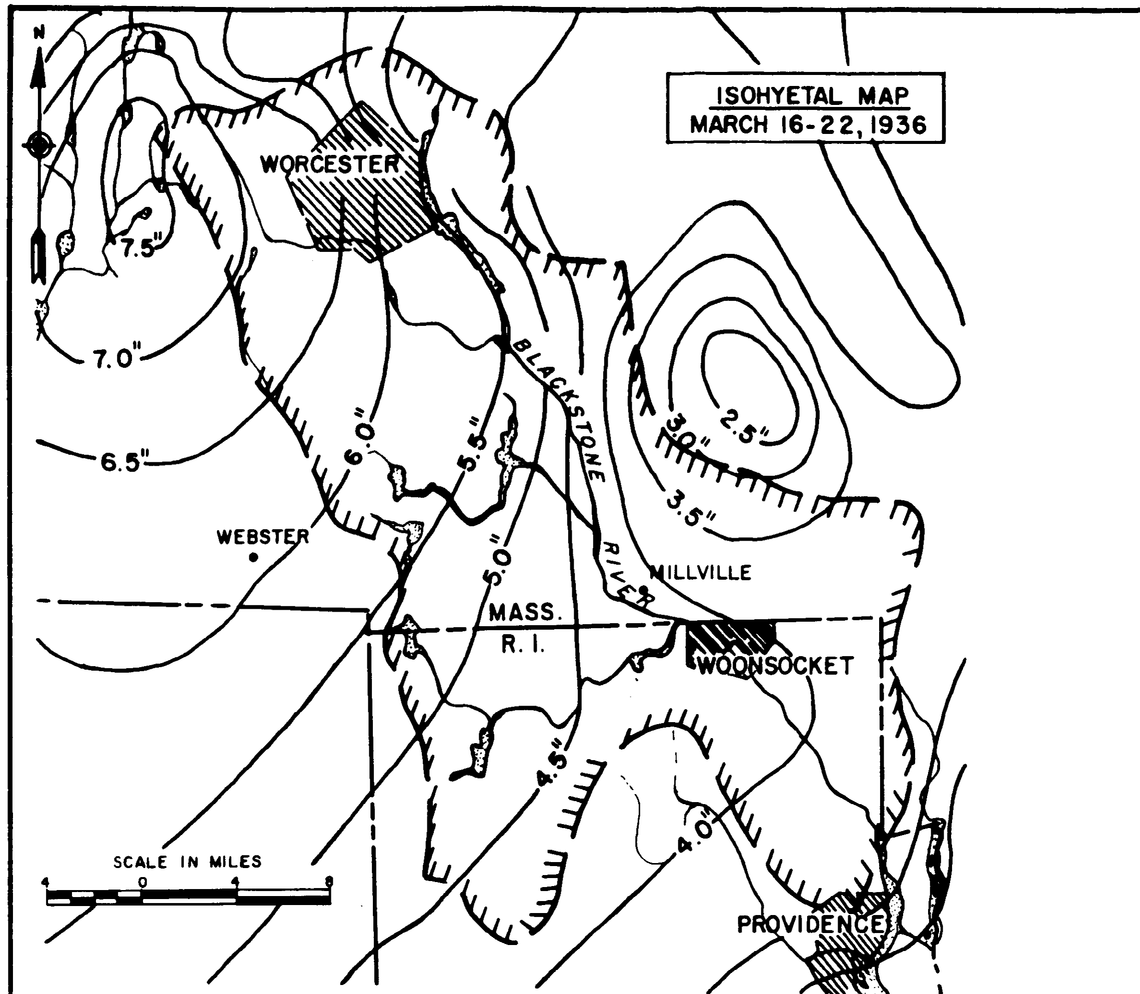
BLACKSTONE RIVER
PLAN AND PROFILE
FLOOD OF AUGUST 1955 - MILE 36 to 48
BLACKSTONE RIVER MASS & R.I.

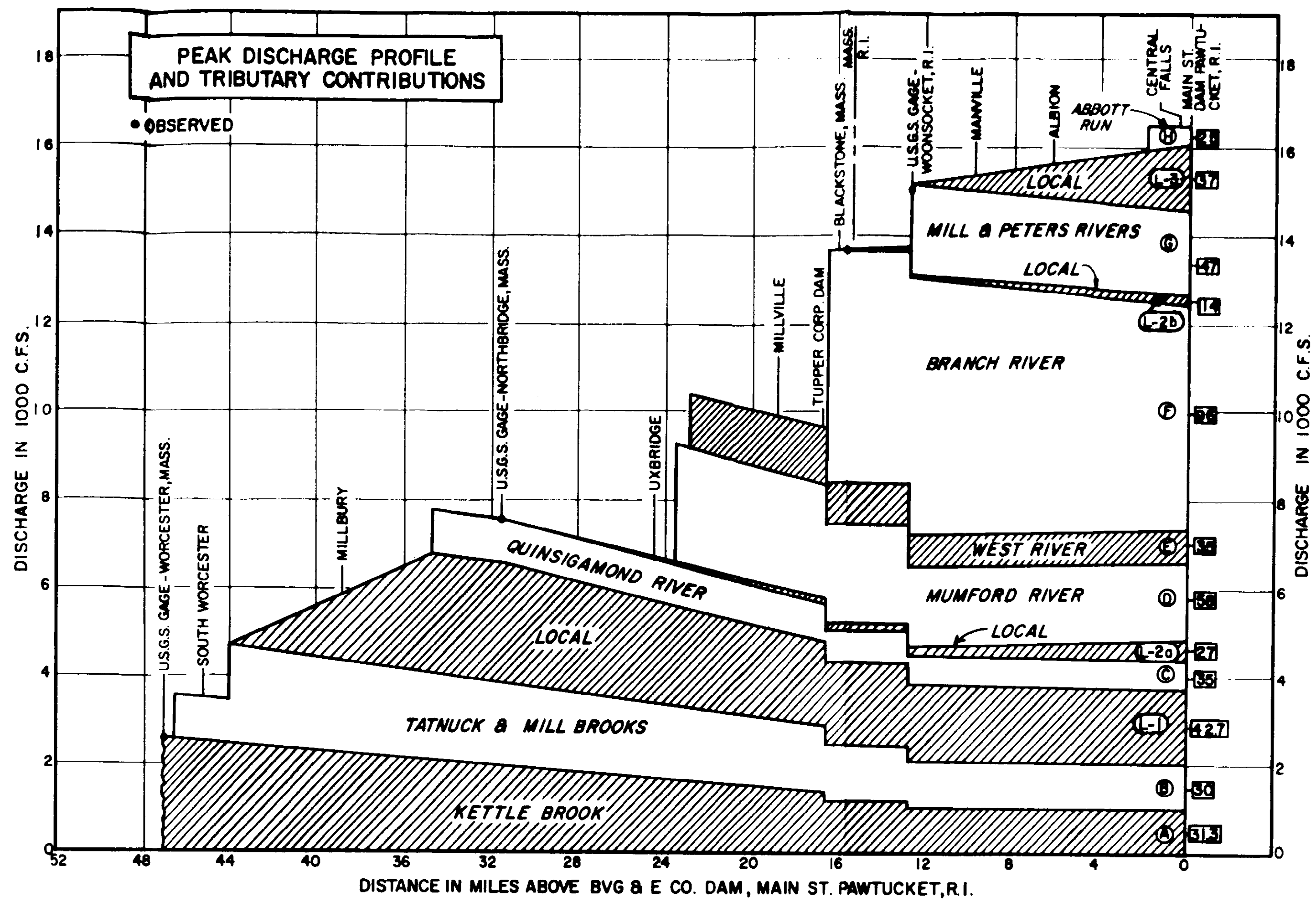
CHIEF H. & H. SECTION
SUBMITTED BY
CHIEF PLANNING BRANCH
APPROVED
APPROVED DATE
CHIEF ENGINEERING DIV. COL. C.E. DIVISION ENGINEER

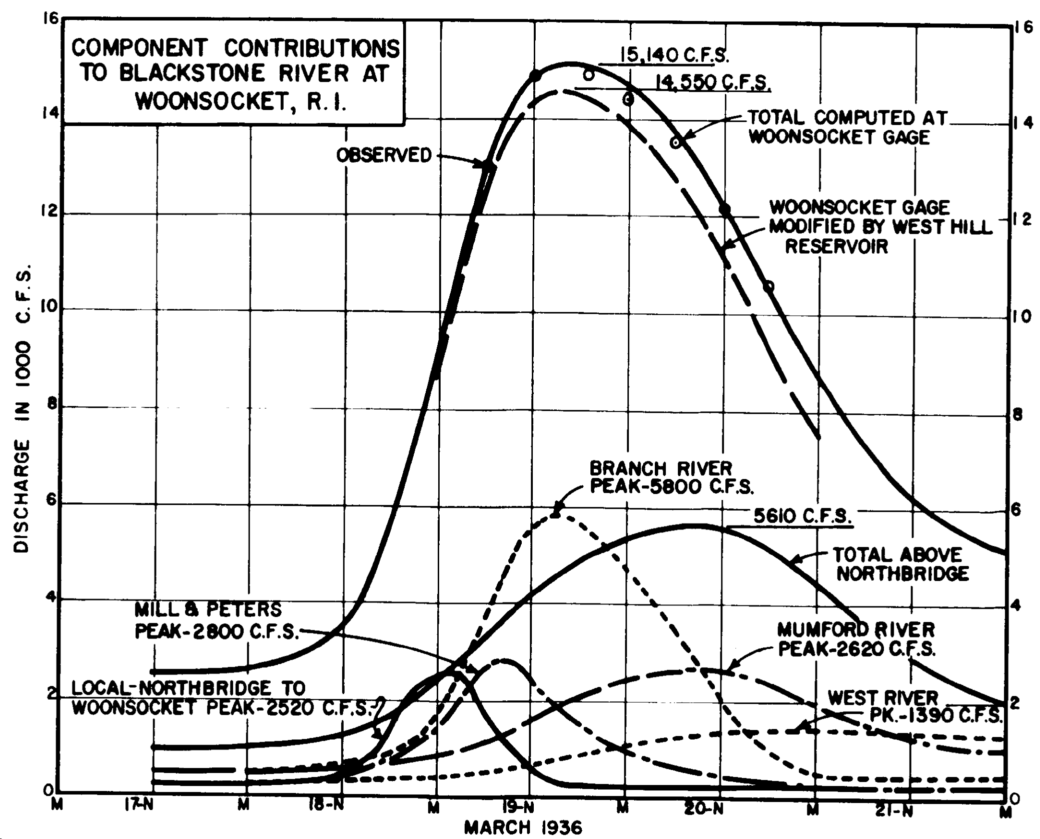
SCALE AS SHOWN
DRAWING NUMBER

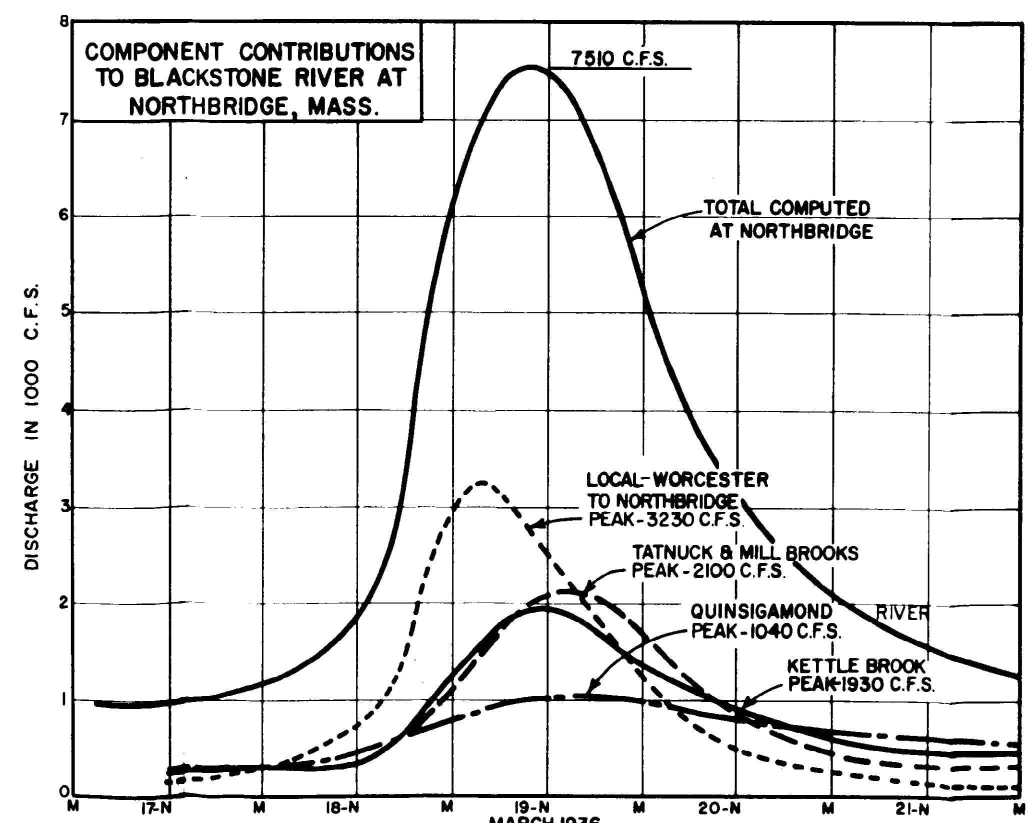
TO ACCOMPANY REPORT
DATED:

PLATE NO. 4









NOTES:

96 Drainage area in square miles

D Areal Sub-division

See Plate No. I

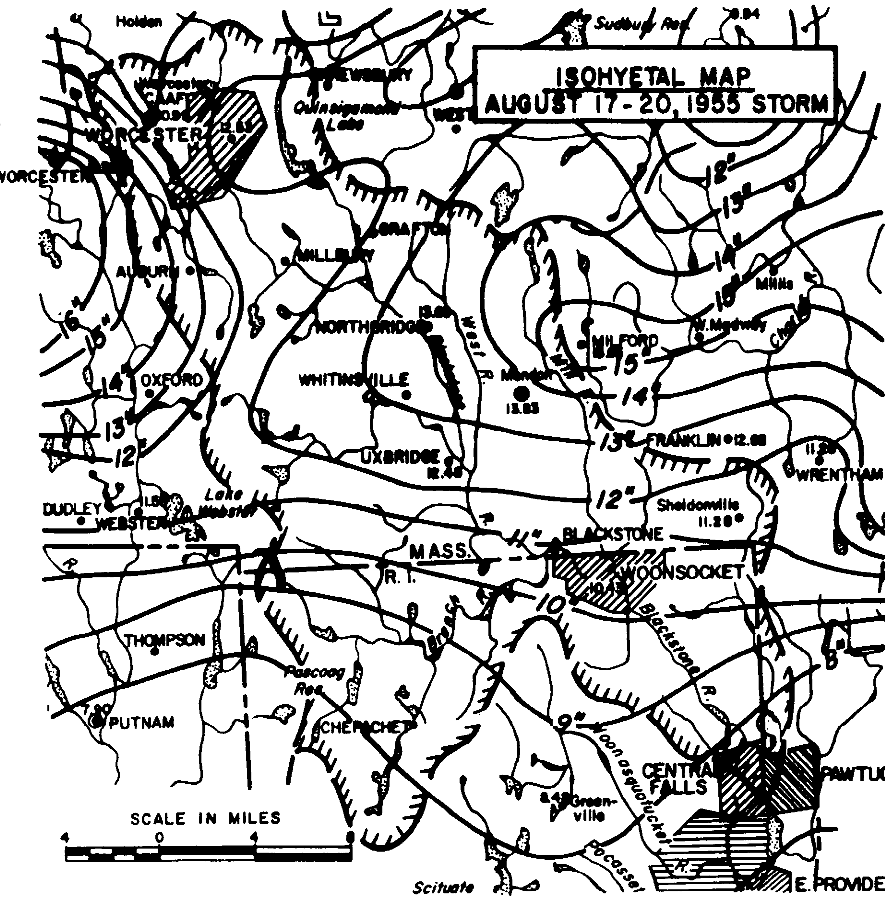
BLACKSTONE RIVER FLOOD CONTROL

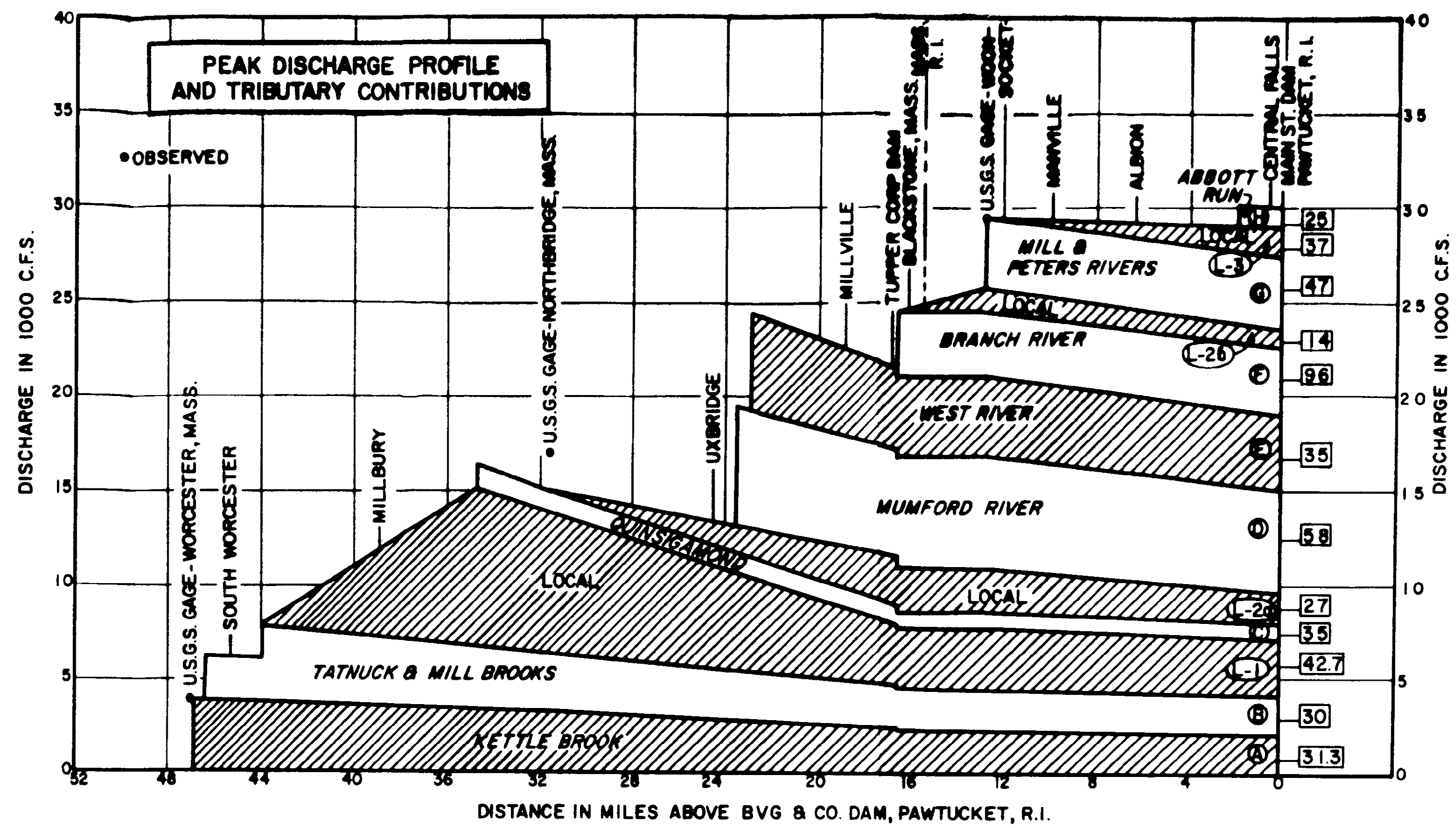
BLACKSTONE RIVER WATERSHED

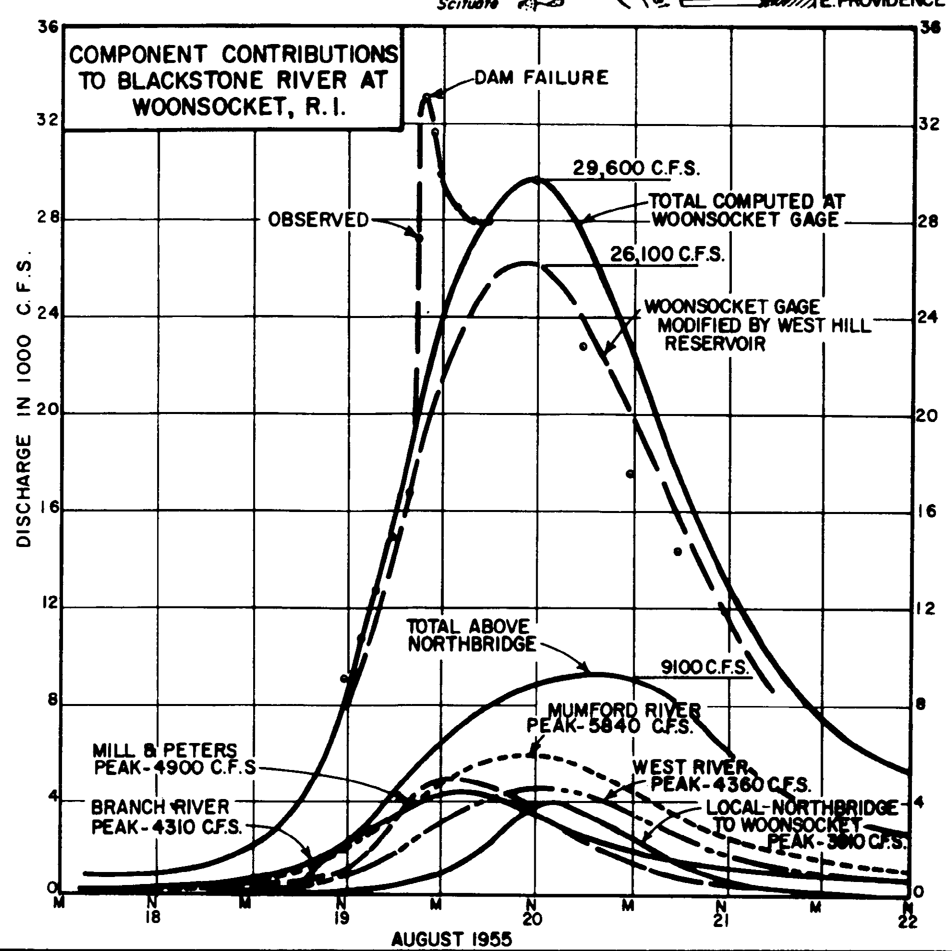
MARCH 1936 FLOOD

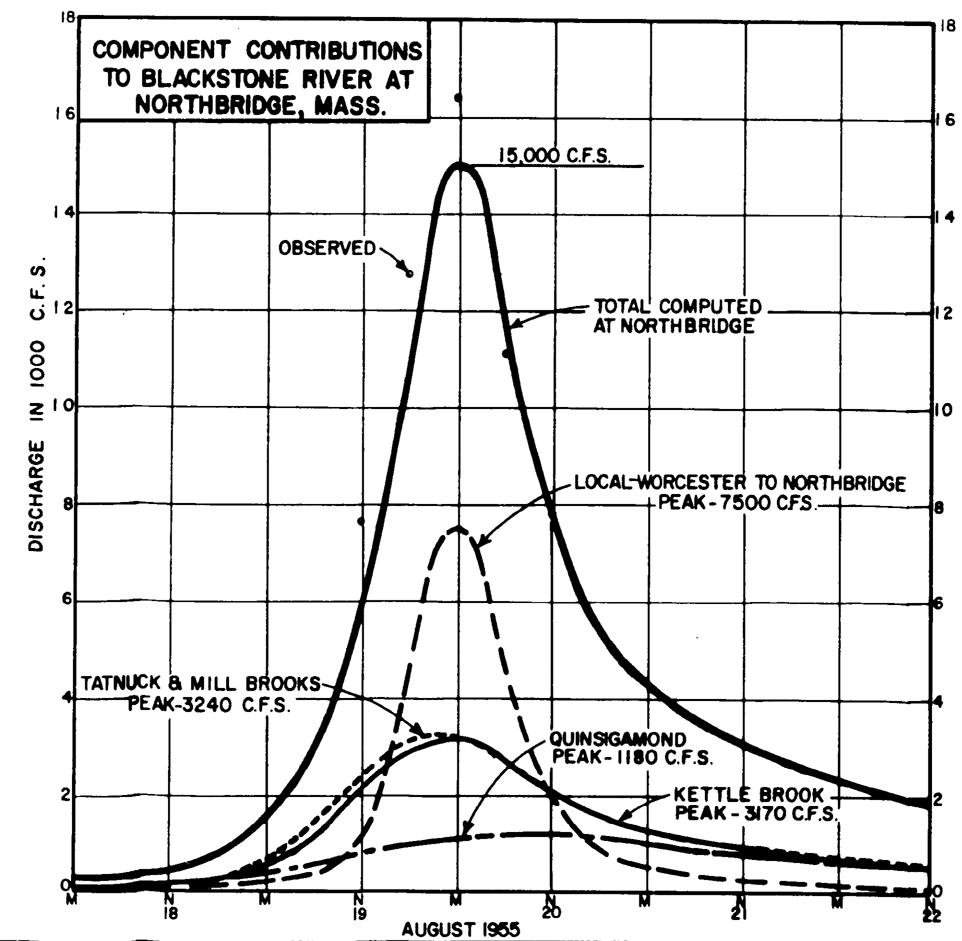
U.S. ARMY ENGINEER DIVISION NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 5









BLACKSTONE RIVER FLOOD CONTROL

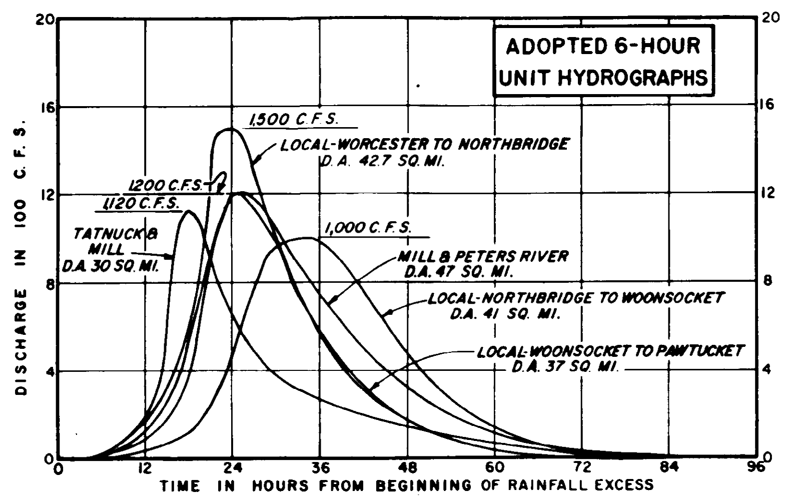
BLACKSTONE RIVER WATERSHED

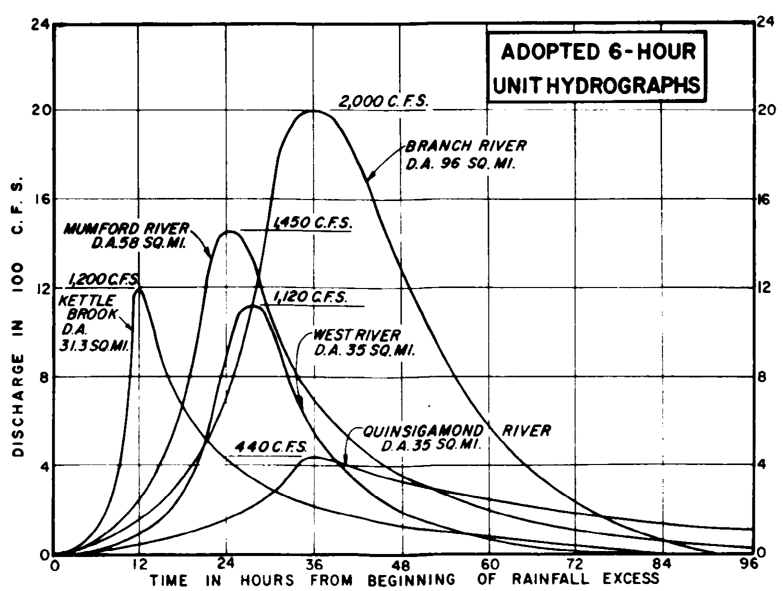
AUGUST 1955 FLOOD

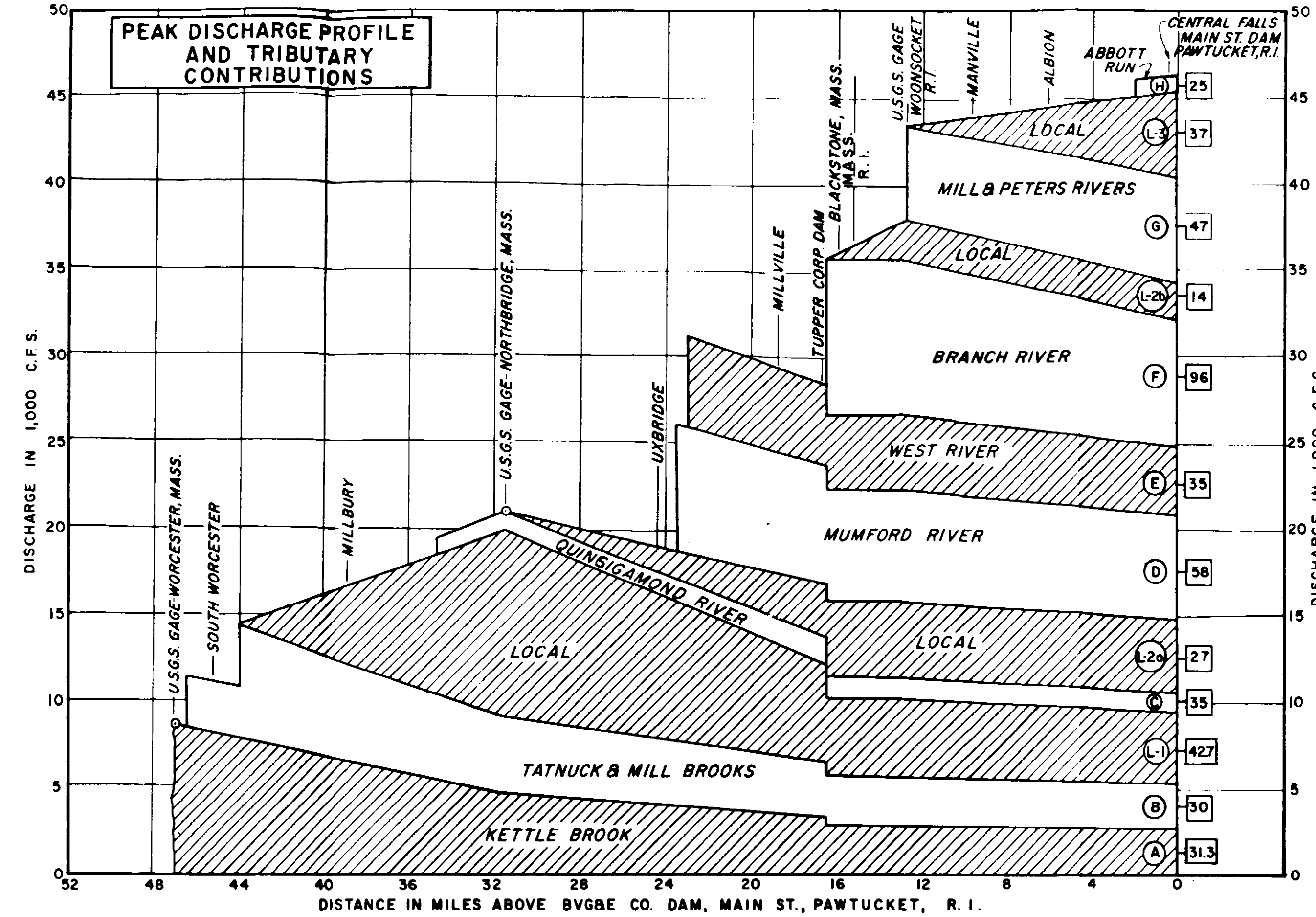
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

PLATE NO. 6

TRIBUTARY	DRAINAGE AREA SQ. MI.	COMPUTED 6-HR. U.H. MAR. 1936	COMPUTED 6-HR. U.H. AUG. 1955	ADOPTED 6-HR. U.H.	tp
KETTLE BROOK	31.3	700	950	1200	9
TATNUCK & MILL RIVERS	30		900	1120	15
LOCAL (L-1)	42.7	1480	1200	1500	21
QUINSIGAMOND RIVER	35		350	440	33
MUMFORD RIVER	58	1100	1200	1450	21
WEST RIVER	35		1000	1120	24
BRANCH RIVER	96	1500	1550	2000	33
LOCAL (L-2a & L-2b)	41		800	1000	30
MILL & PETERS RIVERS	47		760	1200	23
LOCAL (L-3)	37	940	950	1200	21





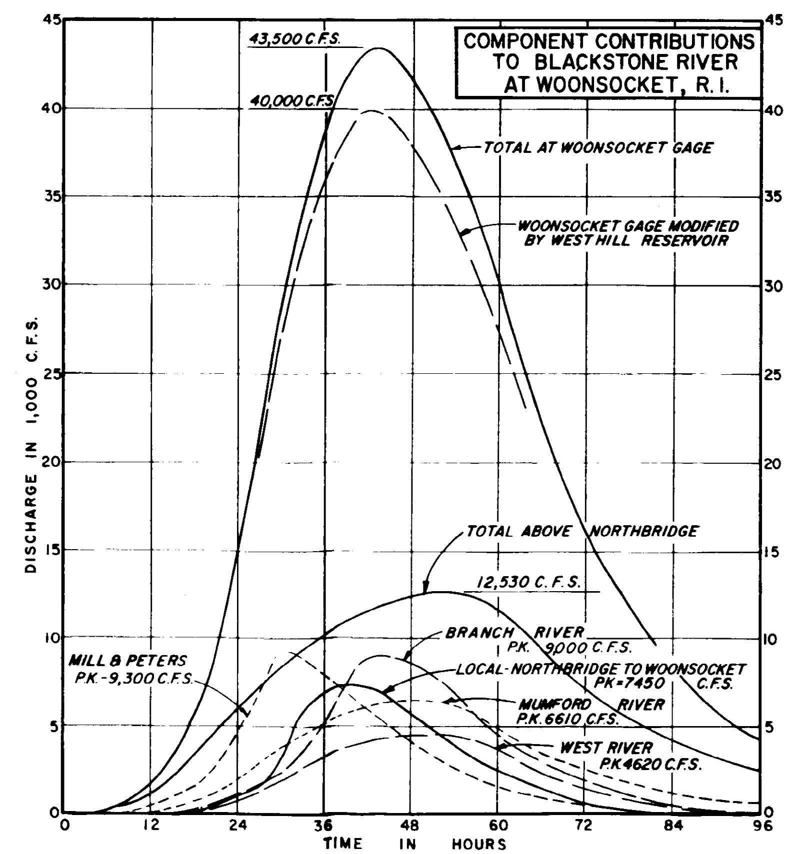


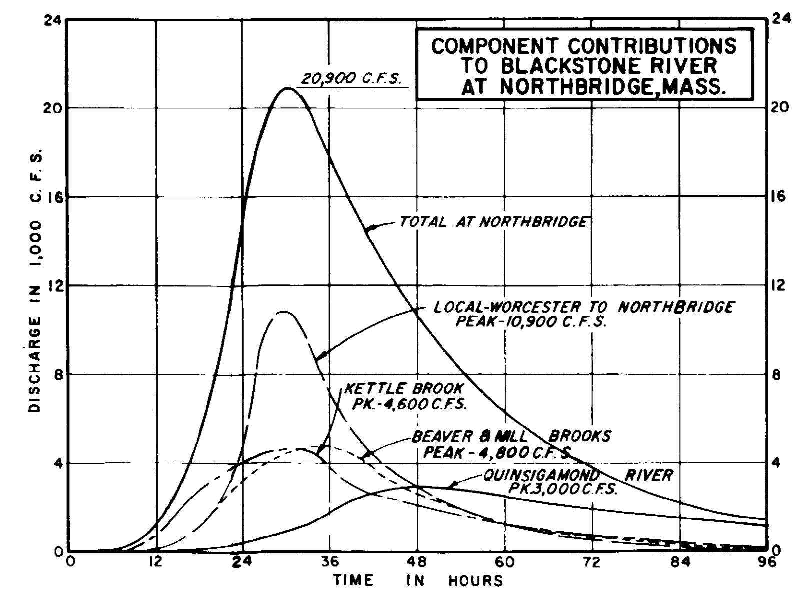
NOTES:

96 Drainage area in sq. mi.

(D) Areal sub-division

See Plate No. 1



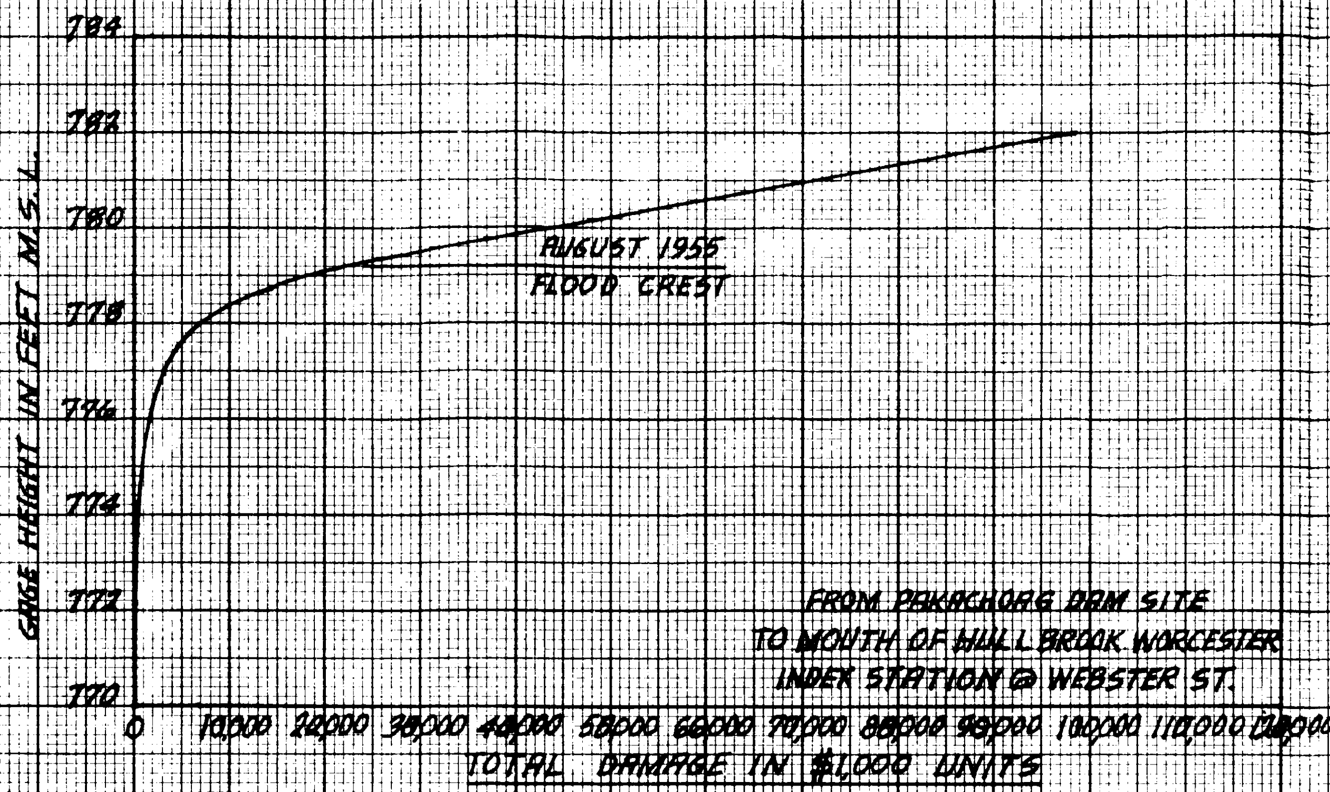


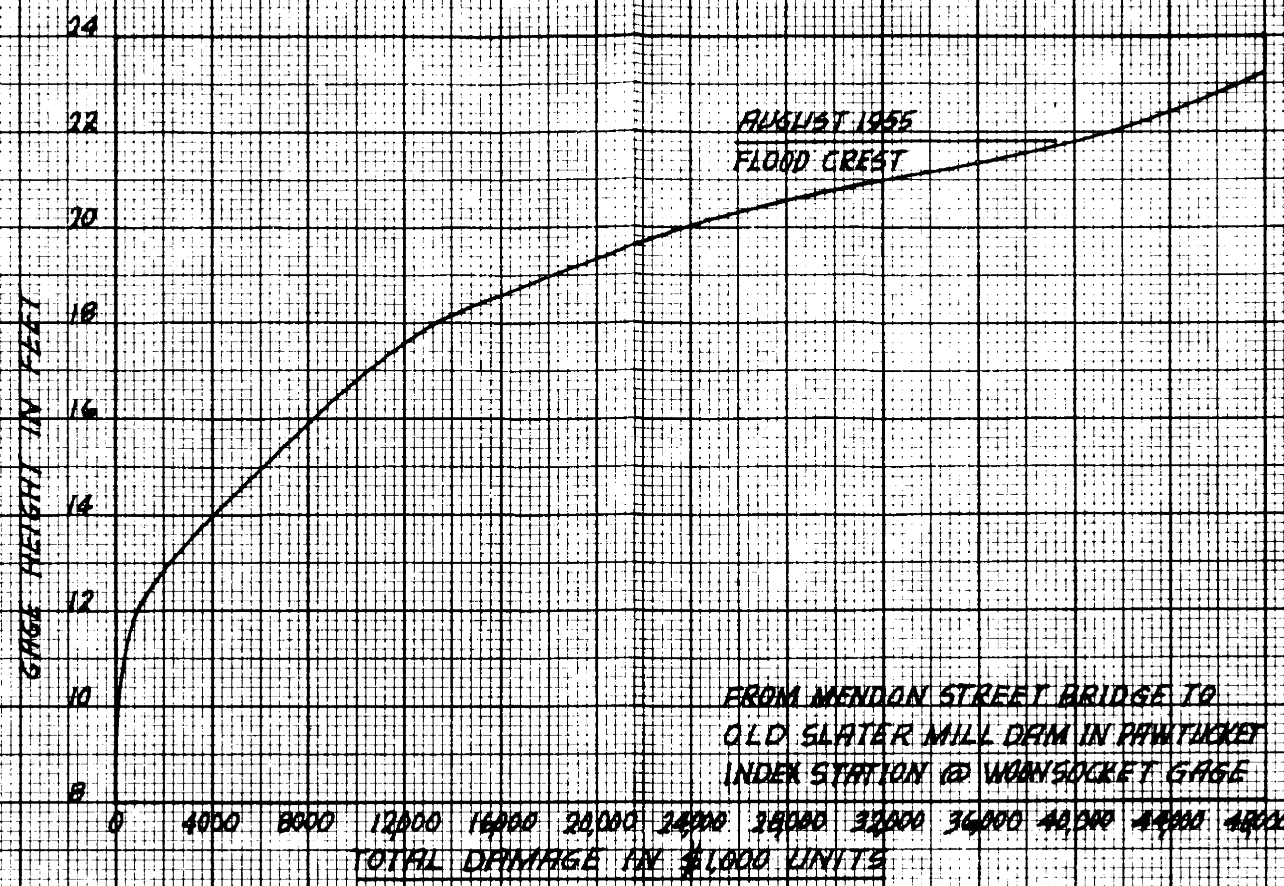
BLACKSTONE RIVER FLOOD CONTROL

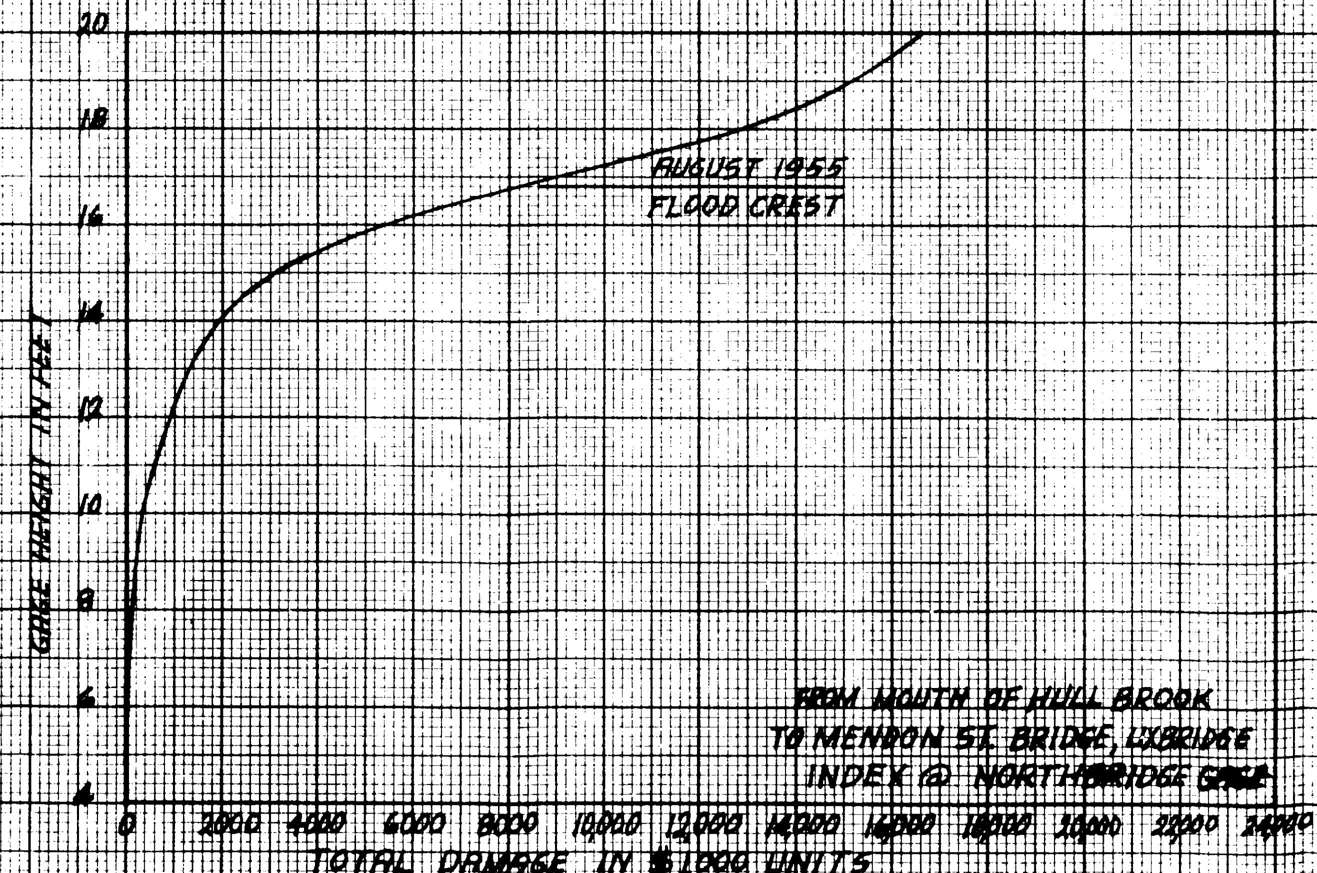
BLACKSTONE RIVER WATERSHED

STANDARD PROJECT FLOOD

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.







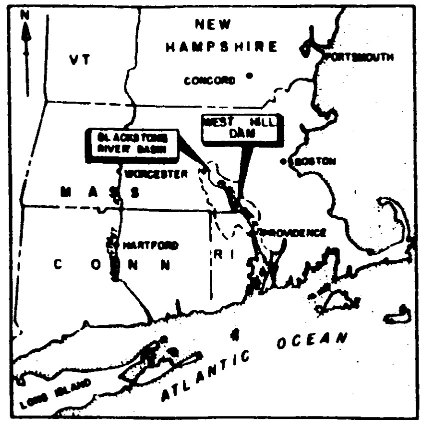
NOTE:
Damage estimates are based on 1965 price levels.

BLACKSTONE RIVER BASIN
REGULATION MANUAL

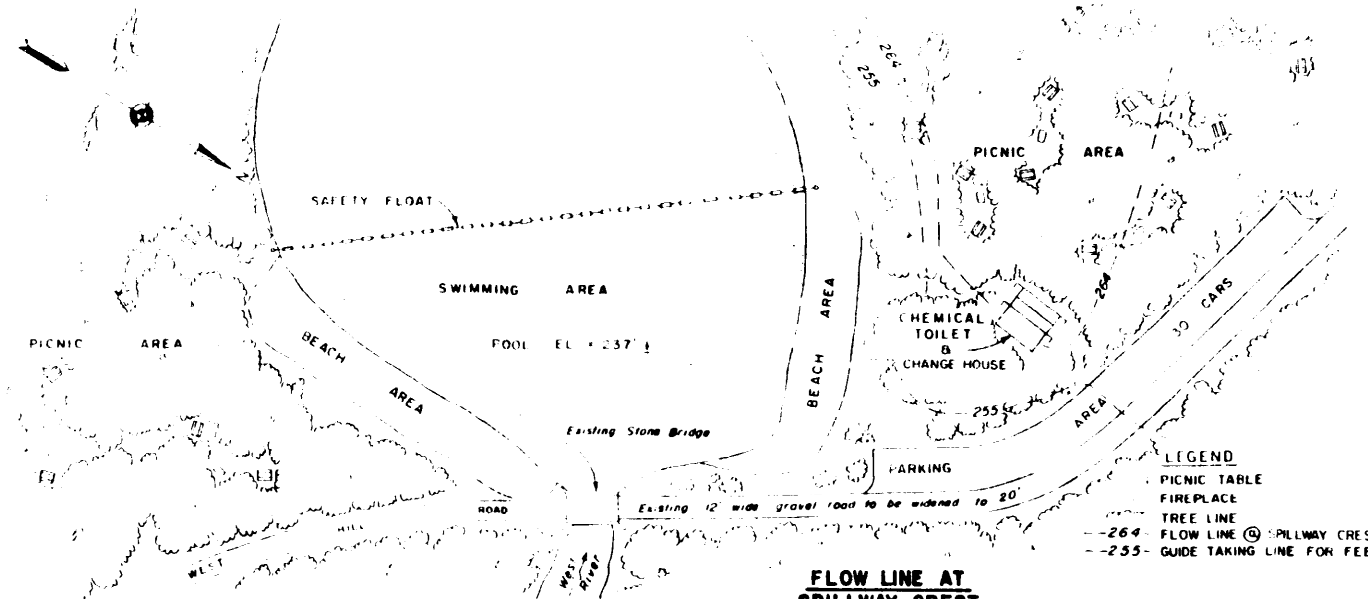
STAGE DAMAGE CURVES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

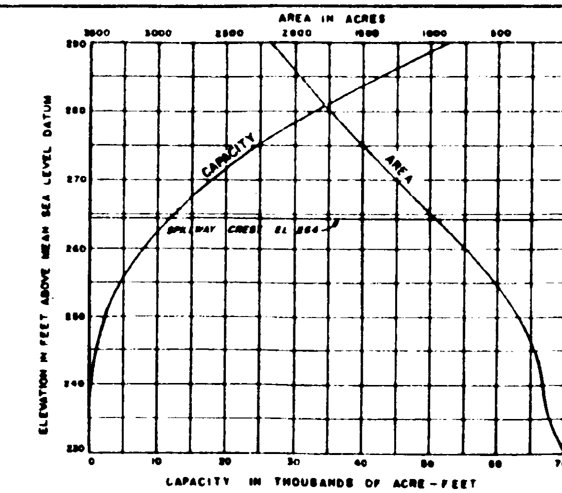
CORPS OF ENGINEERS U S ARMY



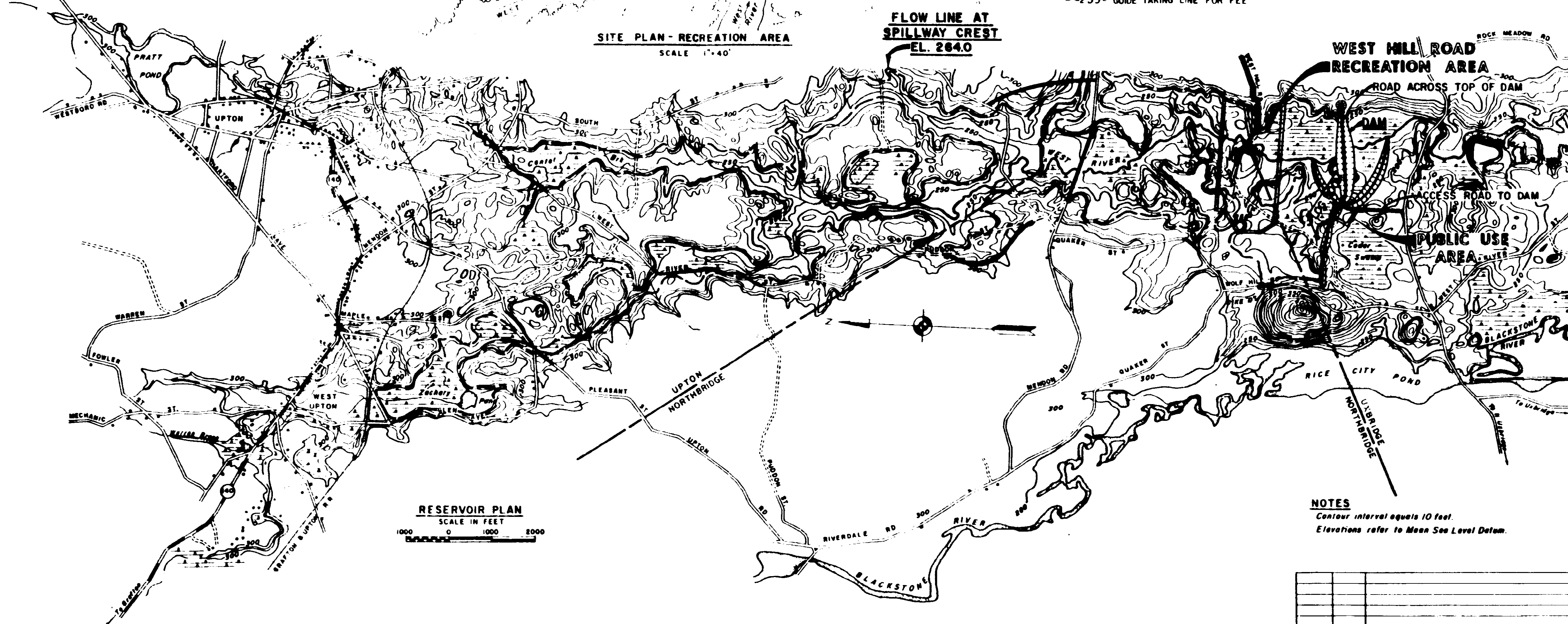
LOCATION MAP
SCALE IN MILES
20 0 20 40



SITE PLAN - RECREATION AREA
SCALE 1"=40'



AREA — CAPACITY CURVES
DRAINAGE AREA 28 SQ MI



RESERVOIR PLAN
SCALE IN FEET
1000 0 1000 2000

PUBLIC USE AREAS						
Name	Proposed Use	Acreage: Above Recreation Pool 237.0	Acreage: Above 5 Year Frequency El 255.0	Acreage: Above Flood Flood Control Pool 264.0	Tree Cover	Terrain
West Hill Road Recreation Area	Public Use	80	15	6	Wooded	Rolling
Public Use Area ⓐ	Public Use	—	—	—	Partially Wooded	Flat

ⓐ Area downstream of dam

LEGEND
Existing numbered routes
Existing paved highways
Existing gravel roads
Completed highway relocation or improvement
Civil township or county line
Public day use areas
Reservoir at spillway crest El 264.0

GRAPHIC SCALE
1"=40' 40 0 40 80

NOTES
Contour interval equals 10 feet.
Elevations refer to Mean Sea Level Datum.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
MASTER PLAN
GENERAL DEVELOPMENT PLAN
WEST RIVER MASSACHUSETTS

APPROVED DATE JAN 1962
SCALE AS SHOWN SPEC NO
DRAWING NUMBER BE-1-1302
SHEET 3

CORPS OF ENGINEERS

U.S. ARMY

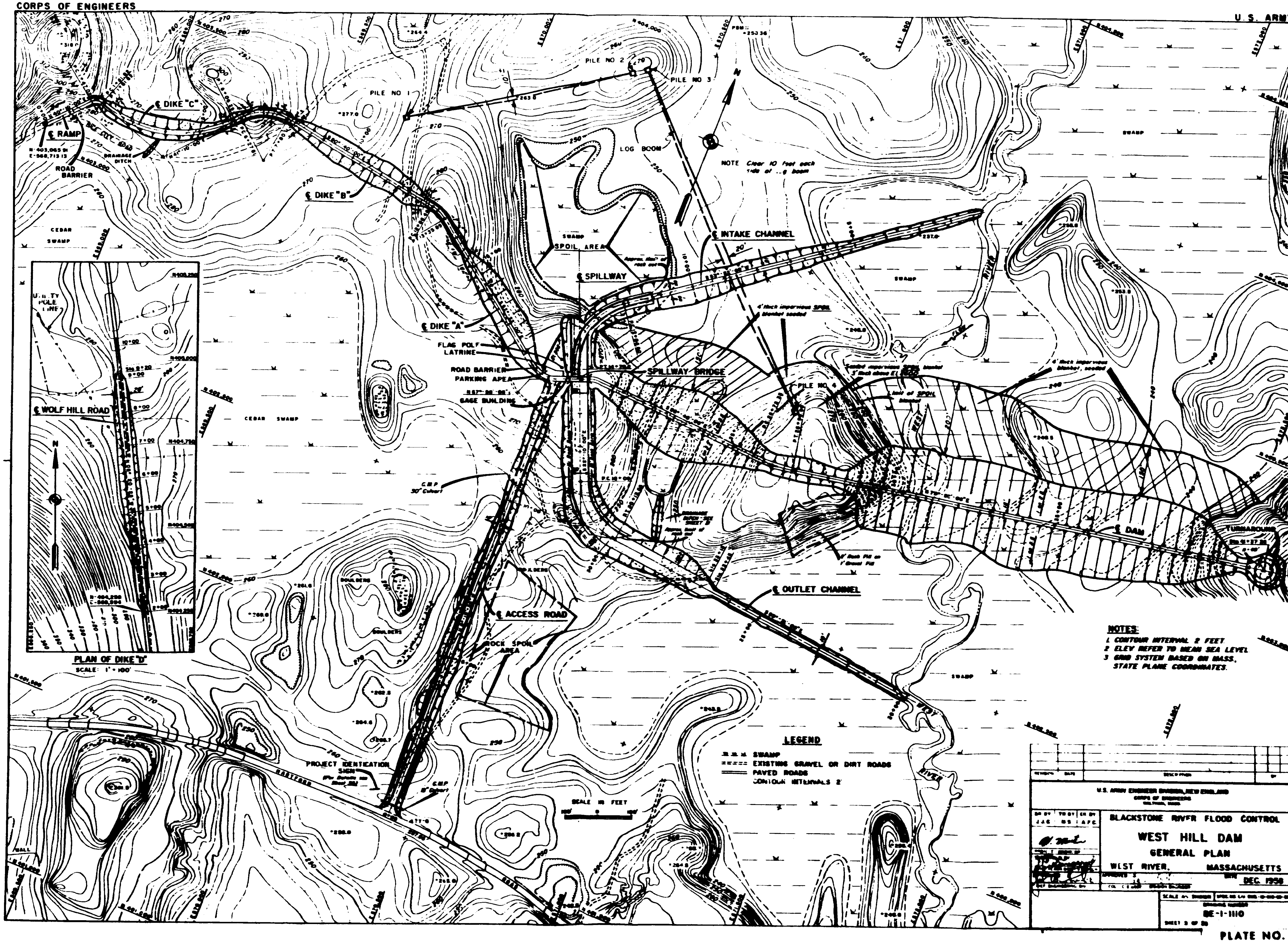


PLATE NO. 10

CORPS OF ENGINEERS

U. S. ARMY

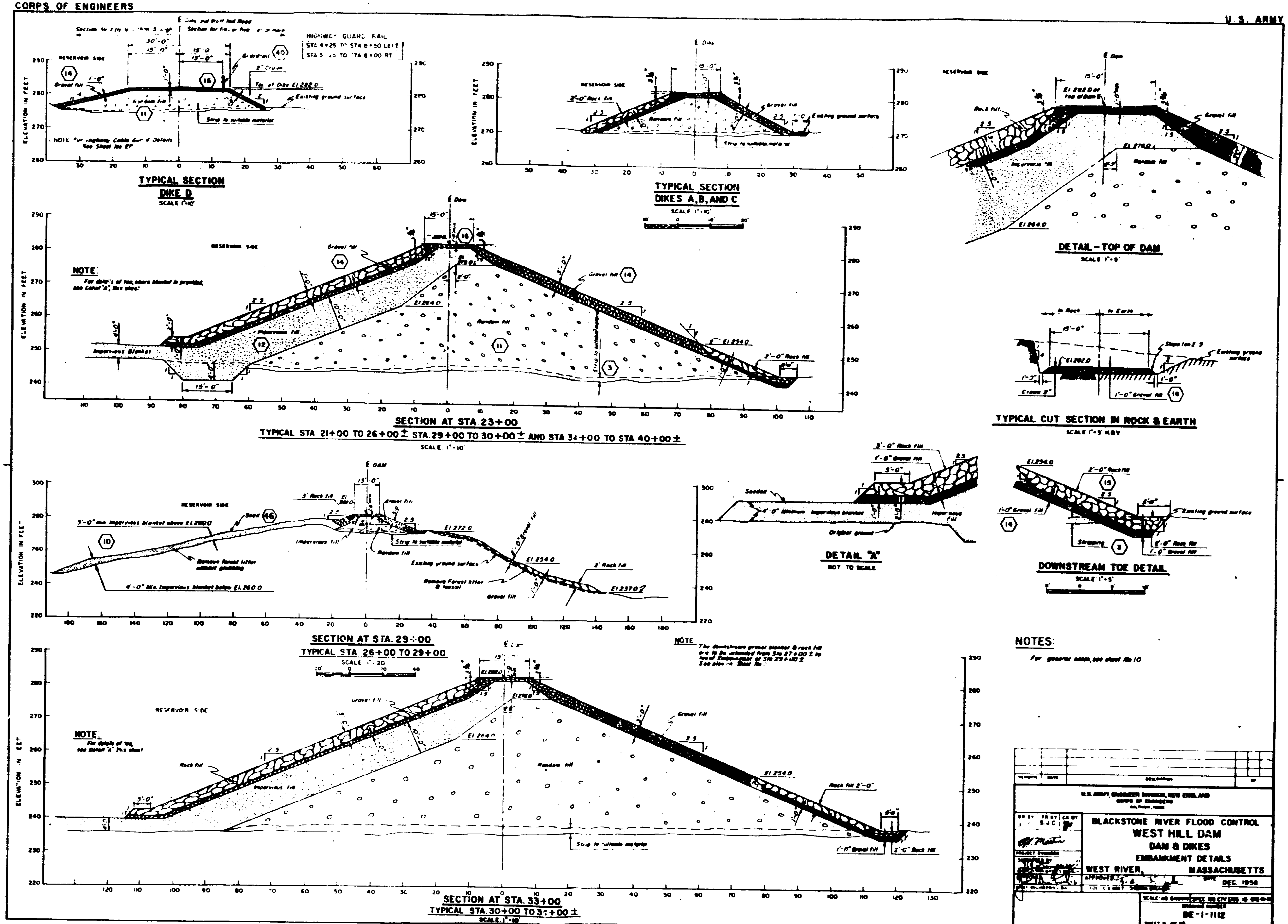
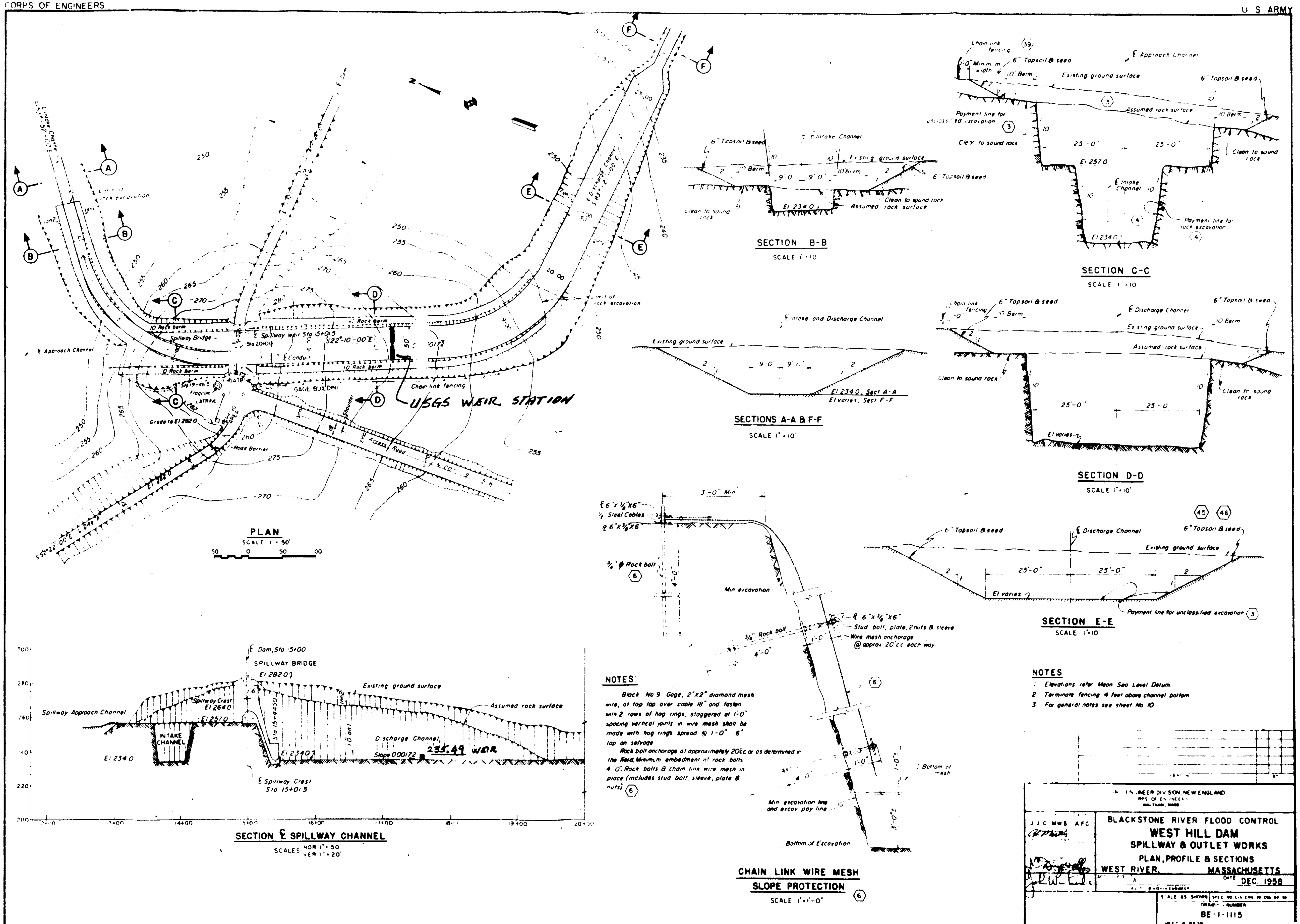
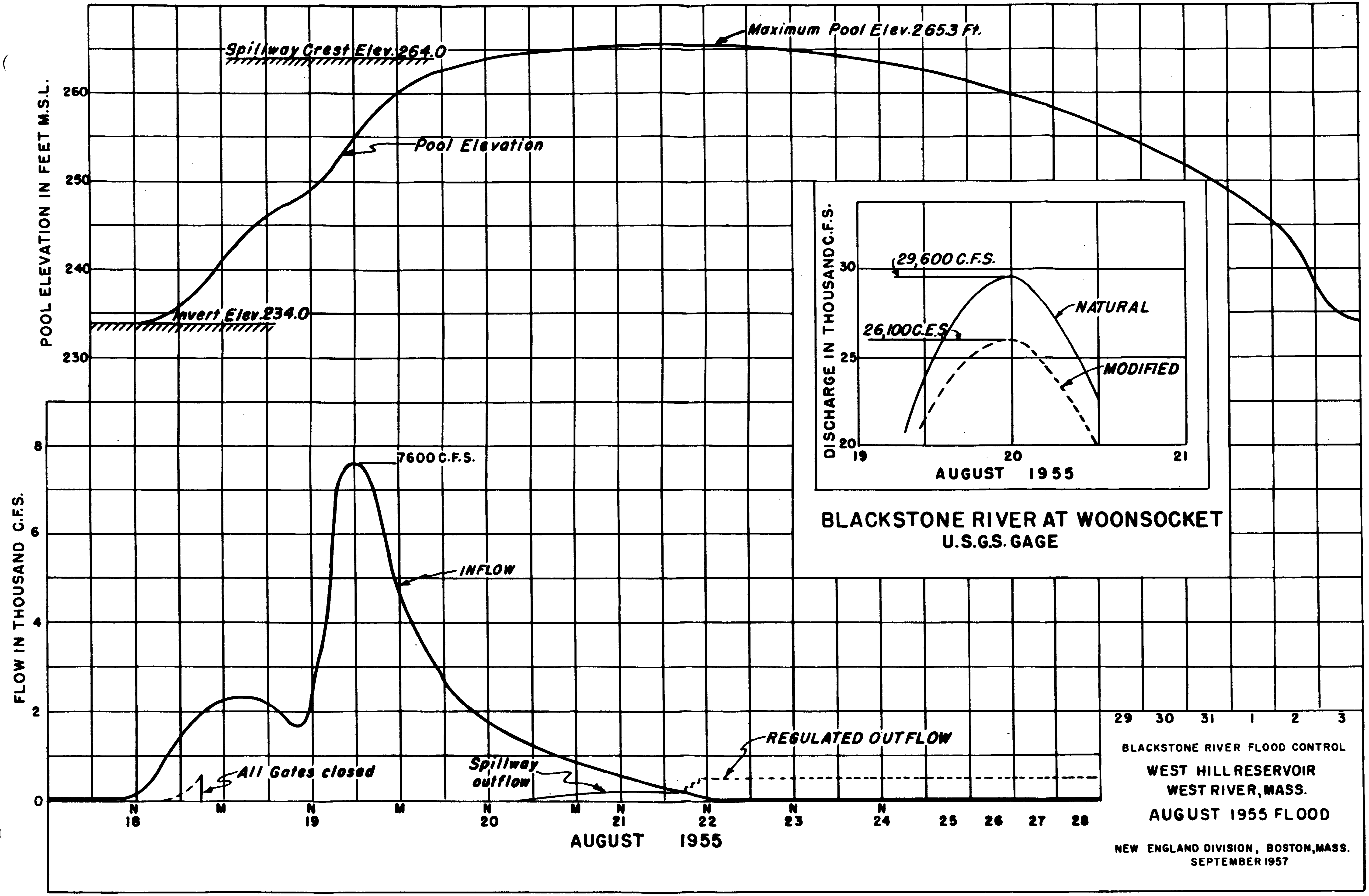


PLATE NO. 11

CORPS OF ENGINEERS U S ARMY





BLACKSTONE RIVER FLOOD CONTROL

WEST HILL RESERVOIR

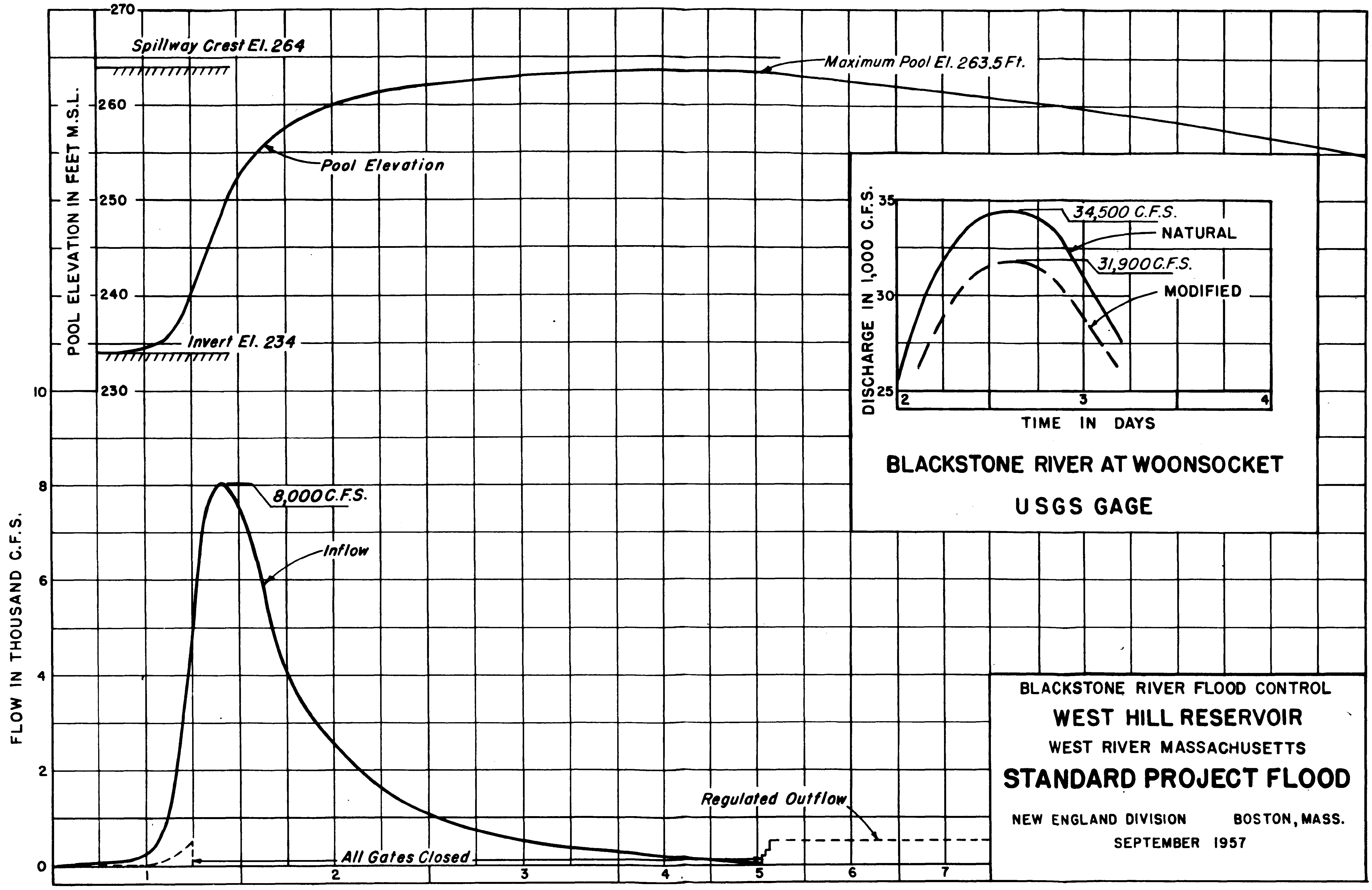
WEST RIVER, MASS.

AUGUST 1955 FLOOD

NEW ENGLAND DIVISION, BOSTON, MASS.

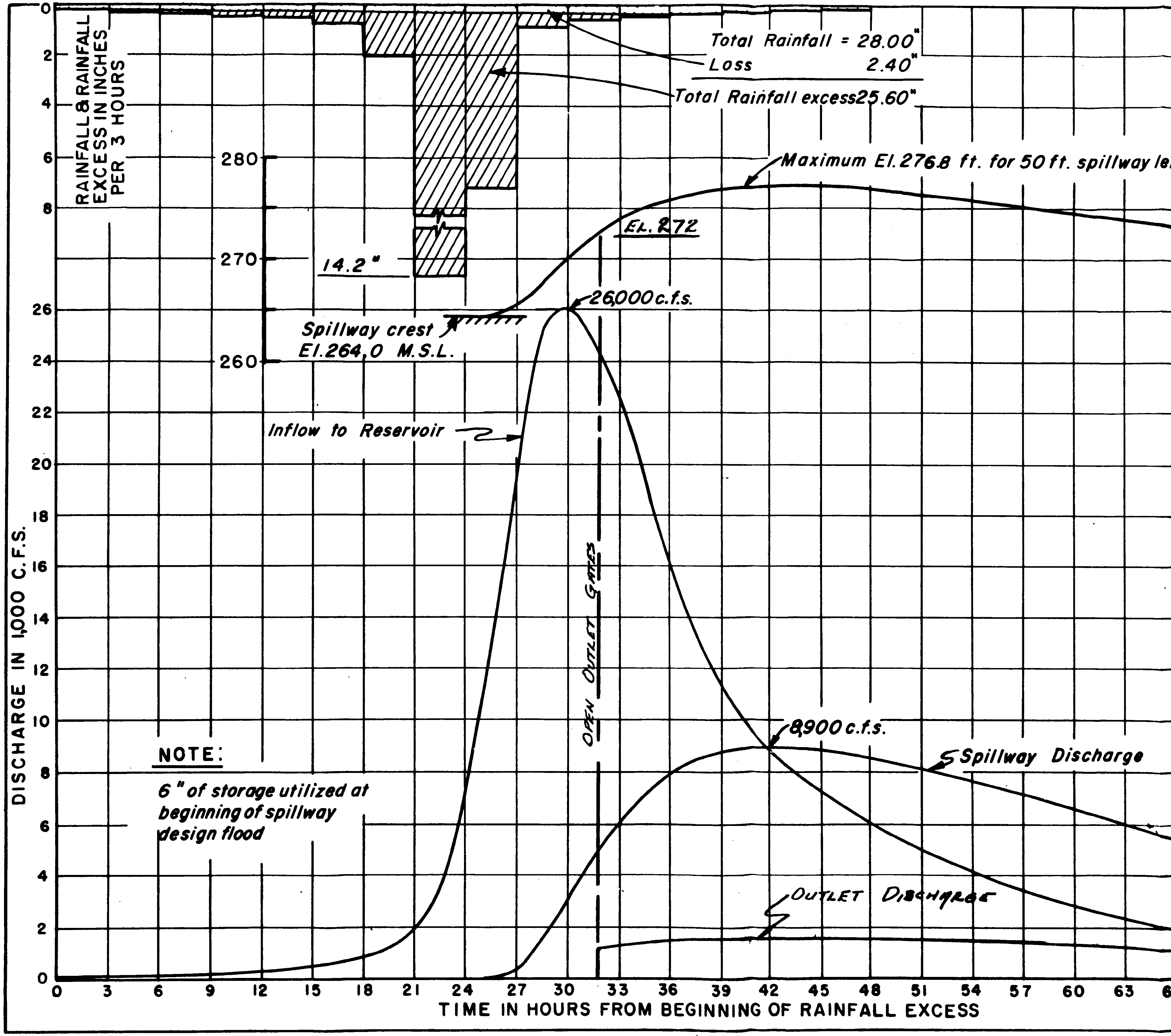
SEPTEMBER 1957

PLATE NO. 13



Spillway Crest El. 264
Maximum Pool El. 263.5 Ft.
Pool Elevation
Invert El. 234
POOL ELEVATION IN FEET M.S.L.
270
260
250
240
230
8,000 C.F.S.
Inflow
All Gates Closed
Regulated Outflow
FLOW IN THOUSAND C.F.S.
10
8
6
4
2
0
1
2
3
4
5
6
7
TIME IN DAYS
34,500 C.F.S.
NATURAL
31,900 C.F.S.
MODIFIED
DISCHARGE IN 1,000 C.F.S.
35
30
25
TIME IN DAYS
BLACKSTONE RIVER AT WOONSOCKET
USGS GAGE
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
WEST RIVER MASSACHUSETTS
STANDARD PROJECT FLOOD
NEW ENGLAND DIVISION BOSTON, MASS.
SEPTEMBER 1957

PLATE NO. 14



BLACKSTONE RIVER FLOOD CONTROL

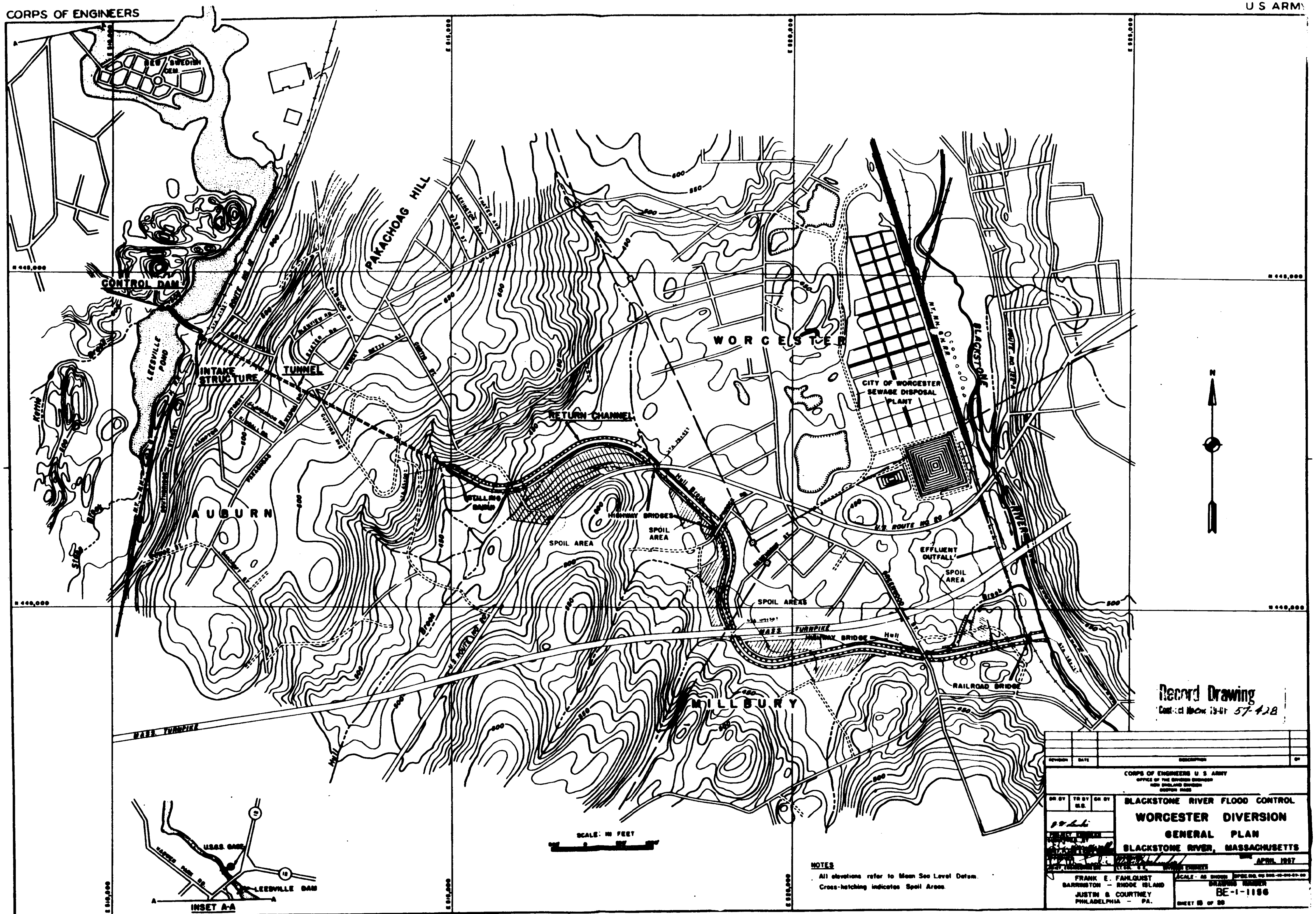
WEST HILL RESERVOIR

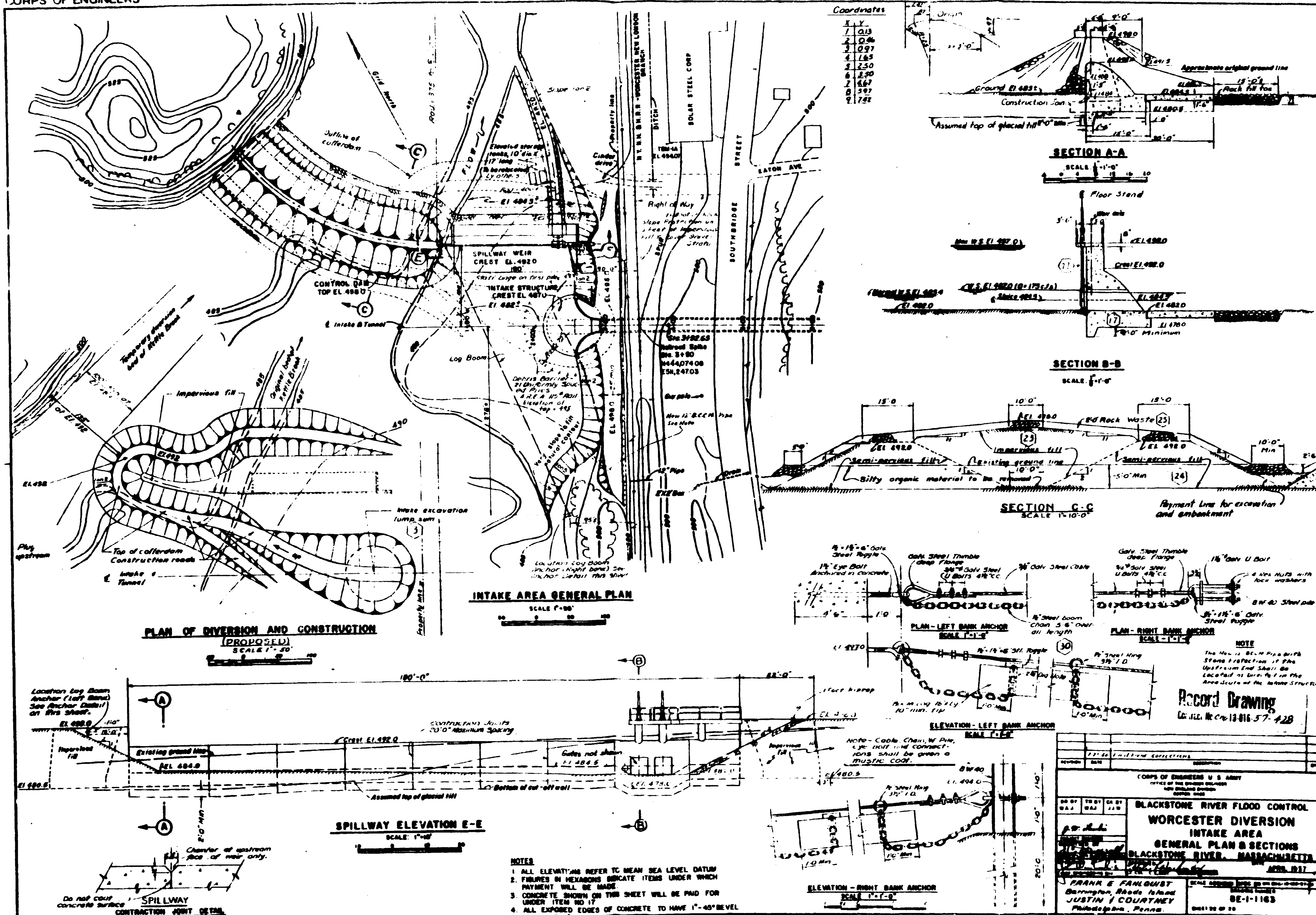
WEST RIVER, MASSACHUSETTS

SPILLWAY DESIGN FLOOD

NEW ENGLAND DIVISION BOSTON, MASS.

SEPTEMBER 1957


CONTROL DAM
LEESVILLE POND
INTAKE STRUCTURE
TUNNEL
PAKACHOAG HILL
RETURN CHANNEL
STILLING BASIN
HIGHWAY BRIDGES
SPOIL AREA
SPOIL AREA
SPOIL AREAS
SPOIL AREA
WORCESTER
CITY OF WORCESTER SEWAGE DISPOSAL PLANT
BLACKSTONE RIVER
U.S. ROUTE NO. 20
EFFLUENT OUTFALL
AUBURN
MILLBURY
MASS. TURNPIKE
MASS. TURNPIKE
HIGHWAY BRIDGE
RAILROAD BRIDGE
N
INSET A-A
USGS GAGE
LEESVILLE DAM
SCALE: IN FEET
NOTES
All elevations refer to Mean Sea Level Datum.
Cross-hatching indicates Spoil Areas.
Record Drawing
57-428
CORPS OF ENGINEERS U S ARMY
BLACKSTONE RIVER FLOOD CONTROL
WORCESTER DIVERSION
GENERAL PLAN
BLACKSTONE RIVER, MASSACHUSETTS
APRIL 1957
FRANK E. FAHLQUIST
BARRINGTON - RHODE ISLAND
JUSTIN & COURTNEY
PHILADELPHIA - PA.
BE-1-1186



PLAN OF DIVERSION AND CONSTRUCTION
(PROPOSED)
SCALE 1"=50'
INTAKE AREA GENERAL PLAN
SCALE 1"=50'
SPILLWAY WEIR CREST EL.492.0
INTAKE STRUCTURE CREST EL.487.0
CONTROL DAM TOP EL.498.0
Log Boom
SOLAR STEEL CORP
SOUTHBRIDGE STREET
EATON AVE
Coordinates
SECTION A-A
SECTION B-B
SECTION C-C
SCALE 1"=10'-0"
Semi-pervious fill
Impervious fill
Silty organic material to be removed
Payment line for excavation and embankment
PLAN - LEFT BANK ANCHOR
PLAN - RIGHT BANK ANCHOR
ELEVATION - LEFT BANK ANCHOR
ELEVATION - RIGHT BANK ANCHOR
SPILLWAY ELEVATION E-E
SPILLWAY CONTRACTION JOINT DETAIL
Do not cast concrete surface
Chamfer at upstream face of weir only.
Note - Cable Chain, W Pile, eye bolt and connections shall be given a mastic coat.
NOTES
1. ALL ELEVATIONS REFER TO MEAN SEA LEVEL DATUM
2. FIGURES IN HEXAGONS INDICATE ITEMS UNDER WHICH PAYMENT WILL BE MADE.
3. CONCRETE SHOWN ON THIS SHEET WILL BE PAID FOR UNDER ITEM NO 17
4. ALL EXPOSED EDGES OF CONCRETE TO HAVE 1"-45° BEVEL
Record Drawing
CORPS OF ENGINEERS U.S. ARMY
BLACKSTONE RIVER FLOOD CONTROL
WORCESTER DIVERSION
INTAKE AREA
GENERAL PLAN & SECTIONS
BLACKSTONE RIVER, MASSACHUSETTS
APRIL 1957
FRANK E FAHLQUIST
Barrington, Rhode Island
JUSTIN I COURTNEY
Philadelphia, Penna.
BE-1-1163

OPERATIONS CHART

RIVER STAGE AT DAM (USE FOR RISING FLOOD)	RIVER STAGE AT DAM (USE FOR FALLING FLOOD)	RIVER STAGE AT PUMPING STA. (USE FOR BOTH RISING AND FALLING FLOOD)	GATE SETTINGS #1	GATE SETTINGS #2	GATE SETTINGS #3	GATE SETTINGS #4	OPERATION
		+8.7	14	14	14	14	All tainter gates fully open
		+8.4	14	14	6	14	
		+8.1	14	6	6	14	
		+7.8	6	6	6	14	
		+7.5	6	6	6	6	
		+7.2	6	6	5	6	
		+6.9	6	5	5	6	
		+6.6	5	5	5	6	Effect sand bag closure
		+6.3	5	5	5	5	Check bridges for debris
		+6.0	5	5	4	5	
		+5.8	5	4	4	5	
		+5.6	4	4	4	5	
		+5.4	4	4	4	4	
		+5.2	4	4	3	4	
		+5.0	4	3	3	4	
		+4.8	3	3	3	4	
		+4.6	3	3	3	3	
		+4.4	3	3	2	3	
		+4.2	3	2	2	3	Operate pumping station
		+4.0	2	2	2	3	Start dike patrol
+2.5	+1.0		2	2	2	2	Check Saranac Pond
+2.5	+1.0		2	2	1	2	Start sand bagging as necessary
+2.5	+1.0		2	1	1	2	
+2.5	+1.0		1	1	1	2	
+2.5	+1.0		1	1	1	1	Man pumping station
+2.5	+1.0		1	1	0	1	
+2.5	+1.0		1	0	0	1	
+2.5	+1.0		0	0	0	1	Start regulation of tainter gates
	+1.0		0	0	0	0	according to schedule

NOTE: Allow at least 15 minutes between gate changes except during emergencies.

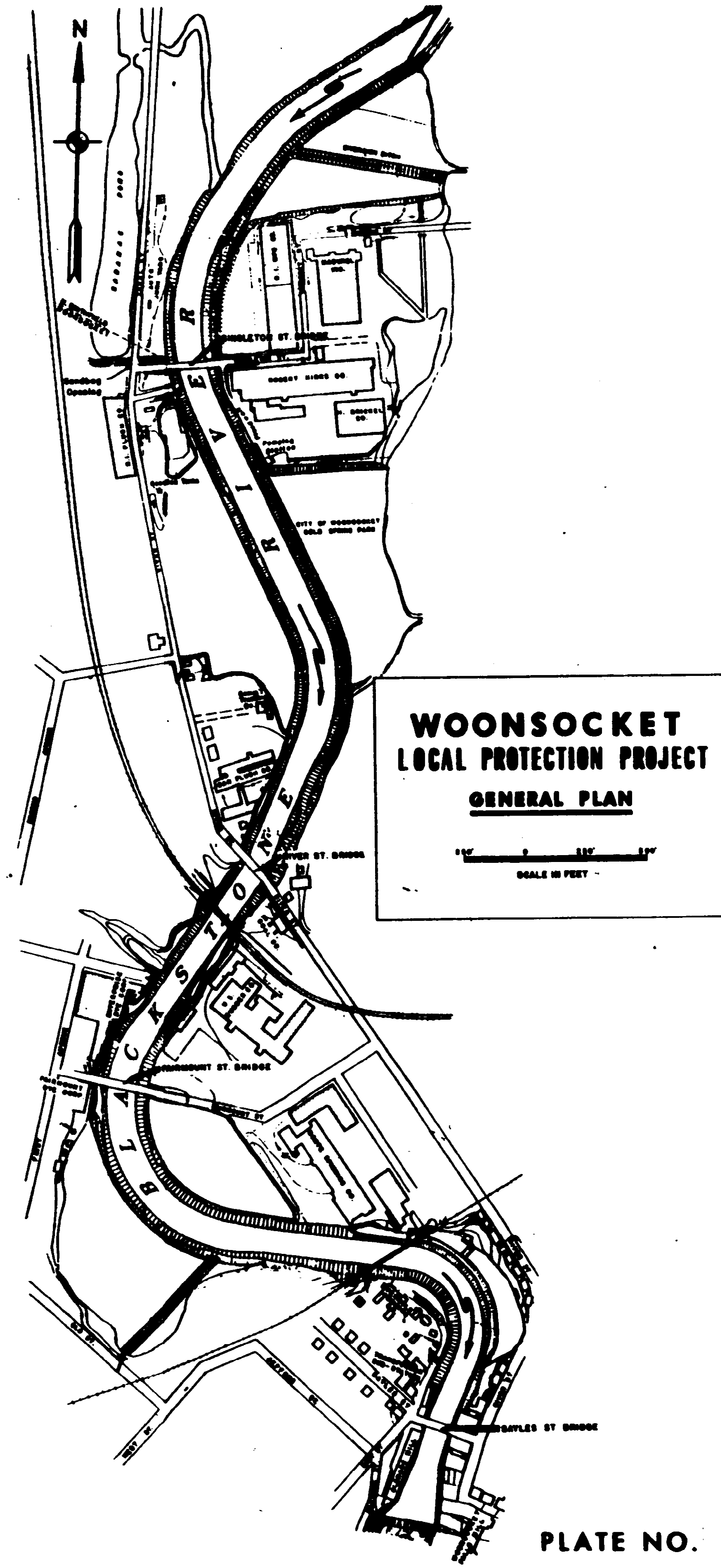
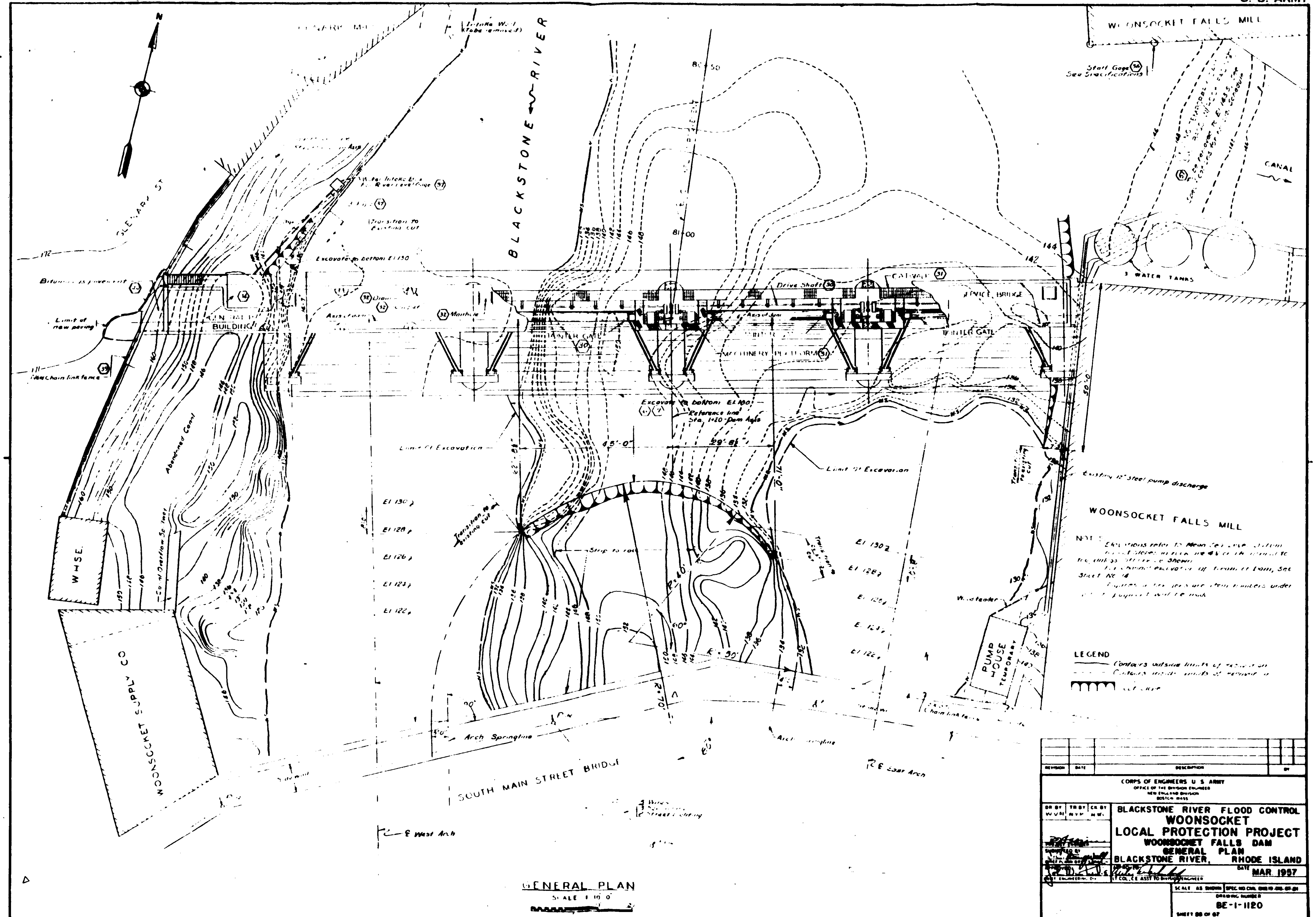
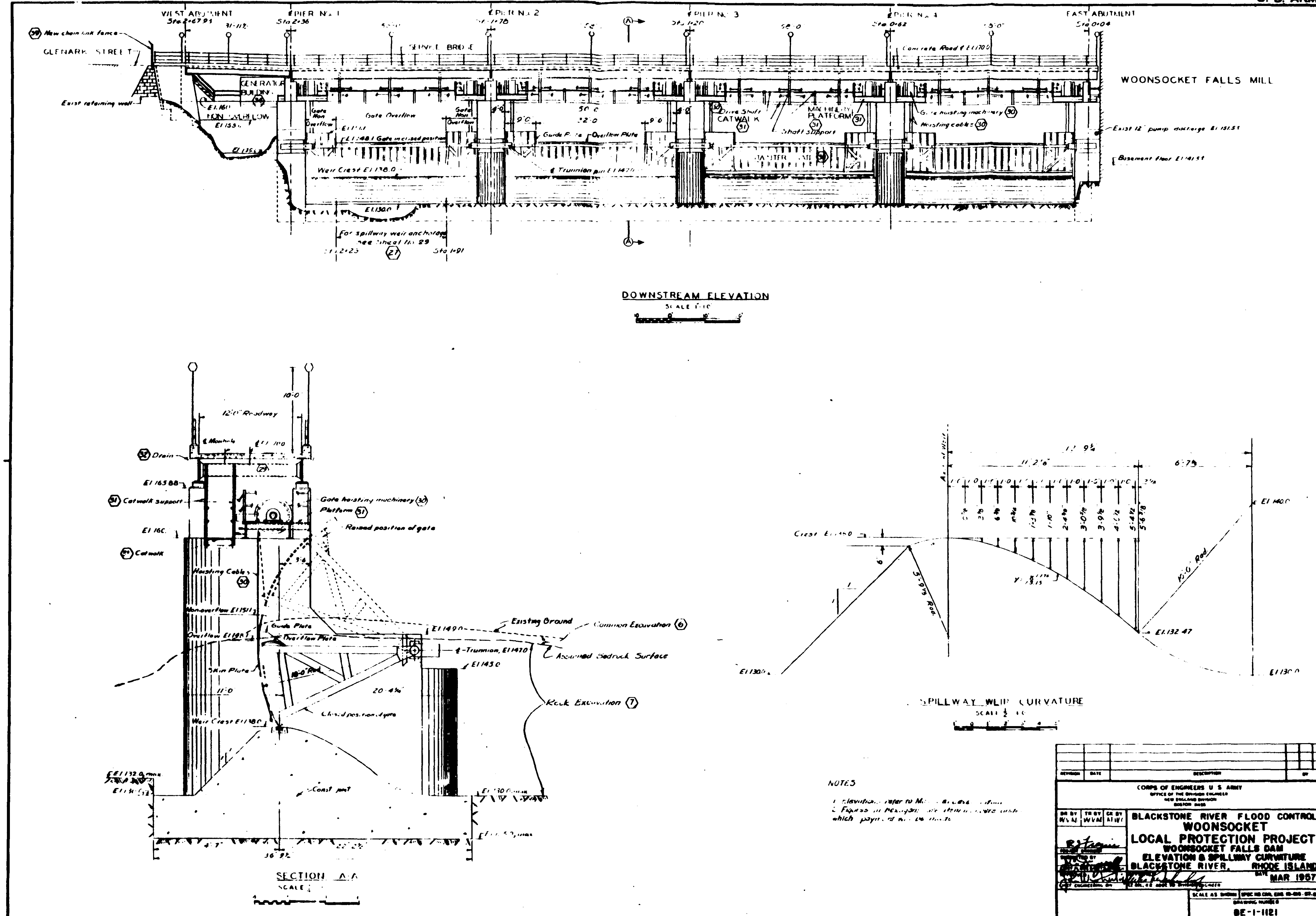


PLATE NO. 18



WOONSOCKET FALLS MILL
BLACKSTONE RIVER
GLENARK ST
CANAL
3 WATER TANKS
SERVICE BRIDGE
MACHINERY PLATFORM
Drive Shaft
Limit of Excavation
Abandoned Canal
WHSE.
WOONSOCKET SUPPLY CO
PUMP HOUSE TEMPORARY
Arch Springline
SOUTH MAIN STREET BRIDGE
℄ West Arch
℄ East Arch
WOONSOCKET FALLS MILL
LEGEND
GENERAL PLAN
CORPS OF ENGINEERS U. S. ARMY
BLACKSTONE RIVER FLOOD CONTROL
WOONSOCKET
LOCAL PROTECTION PROJECT
WOONSOCKET FALLS DAM
GENERAL PLAN
BLACKSTONE RIVER, RHODE ISLAND
MAR 1957
BE-1-1120



NOTES

1. Elevations refer to M... ...
2. Figures in hexagons ... items ... which payment will be made.

CORPS OF ENGINEERS U S ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON MASS

REVISION	DATE	DESCRIPTION	BY

DR BY WVM | TR BY WVM | CK BY AIWC

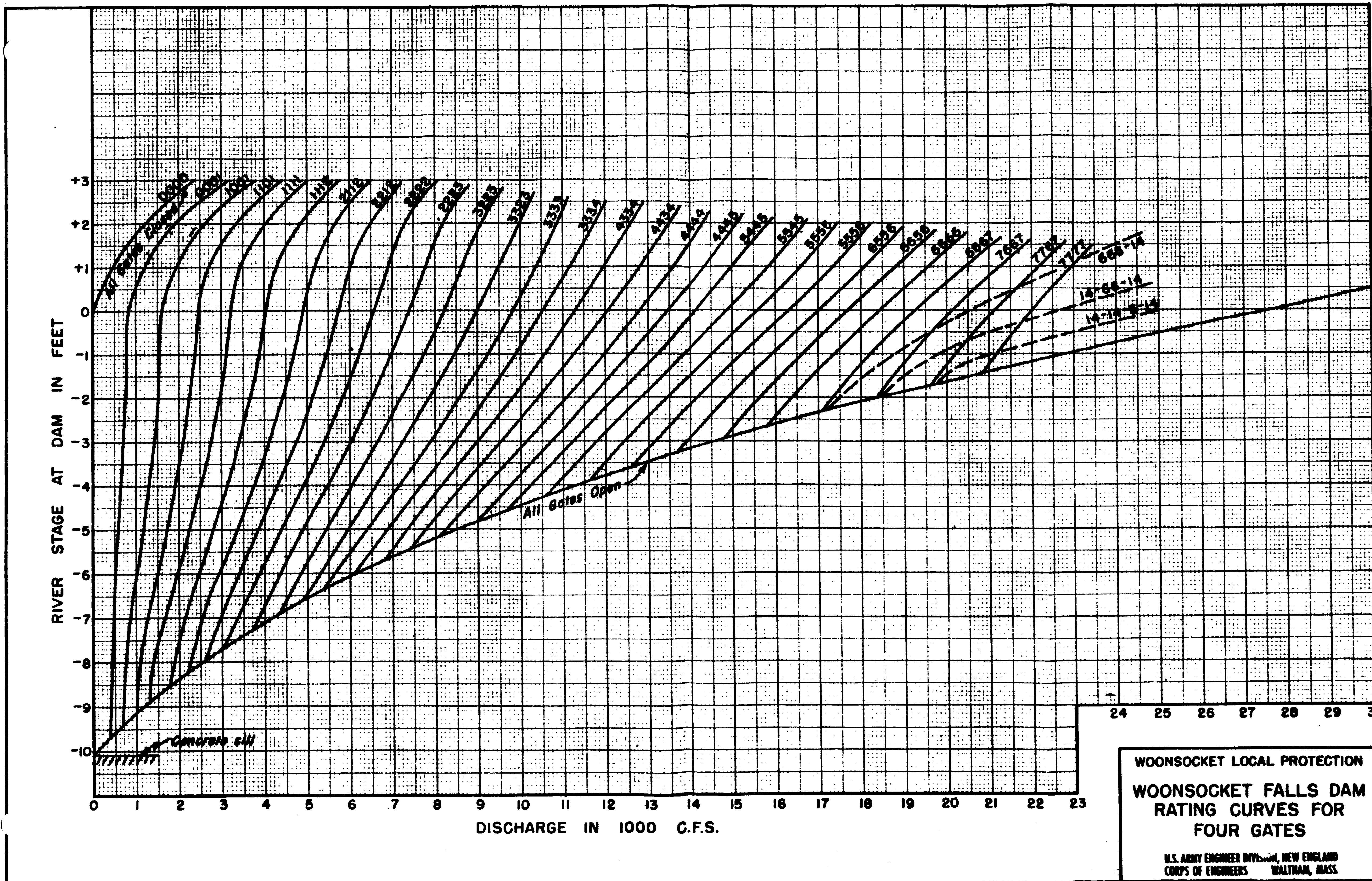
BLACKSTONE RIVER FLOOD CONTROL
WOONSOCKET
LOCAL PROTECTION PROJECT
WOONSOCKET FALLS DAM
ELEVATION & SPILLWAY CURVATURE
BLACKSTONE RIVER, RHODE ISLAND

DATE MAR 1957

SCALE AS SHOWN

DRAWING NUMBER BE-1-1121

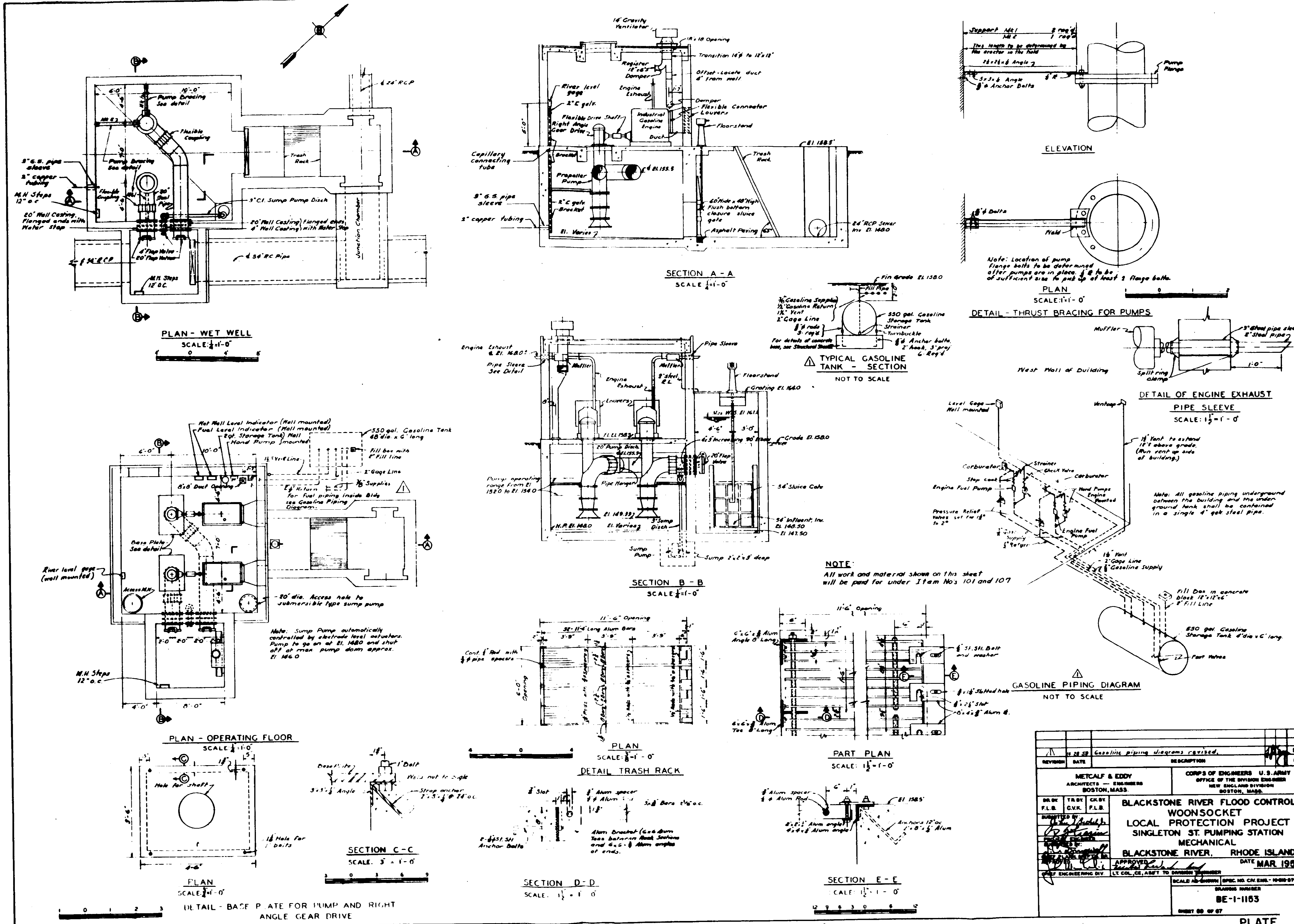
SHEET 27 OF 67



WOONSOCKET LOCAL PROTECTION

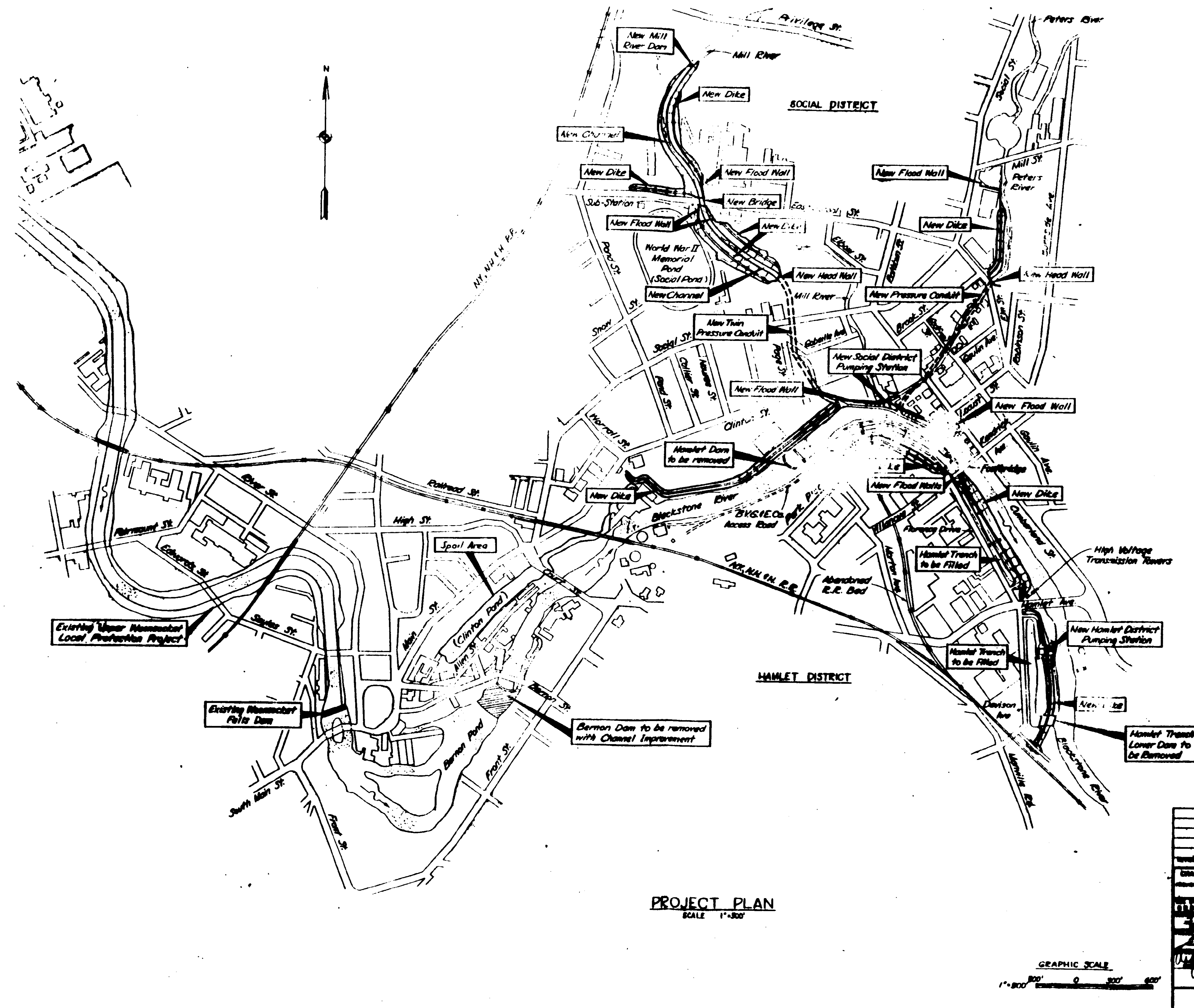
WOONSOCKET FALLS DAM
RATING CURVES FOR
FOUR GATES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.


PLAN - WET WELL
SCALE: 1/4"=1'-0"
SECTION A - A
SCALE 1/4"=1'-0"
ELEVATION
PLAN
SCALE: 1"=1'-0"
DETAIL - THRUST BRACING FOR PUMPS
TYPICAL GASOLINE TANK - SECTION
NOT TO SCALE
DETAIL OF ENGINE EXHAUST PIPE SLEEVE
SCALE: 1 1/2"=1'-0"
PLAN - OPERATING FLOOR
SCALE: 1/4"=1'-0"
SECTION B - B
SCALE 1/4"=1'-0"
NOTE:
All work and material shown on this sheet will be paid for under Item No's 101 and 107
GASOLINE PIPING DIAGRAM
NOT TO SCALE
PLAN
SCALE: 3/4"=1'-0"
DETAIL TRASH RACK
PART PLAN
SCALE: 1 1/2"=1'-0"
PLAN
SCALE: 1"=1'-0"
DETAIL - BASE PLATE FOR PUMP AND RIGHT ANGLE GEAR DRIVE
SECTION C - C
SECTION D - D
SECTION E - E
Gasoline piping diagrams revised.
REVISION
DATE
DESCRIPTION
BY
METCALF & EDDY
ARCHITECTS — ENGINEERS
BOSTON, MASS.
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.
DR. BY F.L.B.
TR. BY C.V.K.
CK. BY F.L.B.
BLACKSTONE RIVER FLOOD CONTROL
WOONSOCKET
LOCAL PROTECTION PROJECT
SINGLETON ST. PUMPING STATION
MECHANICAL
BLACKSTONE RIVER, RHODE ISLAND
SUBMITTED BY:
APPROVED
CHIEF ENGINEERING DIV.
LT. COL., CE, ASS'T TO DIVISION ENGINEER
DATE MAR. 1957
DRAWING NUMBER
BE-1-1163

CORPS OF ENGINEERS

U. S. ARMY



LEGEND		
NEW	EXISTING	DESCRIPTION
x 265.7	x 265.7	ELEVATIONS
266	266	CONTOURS
		BUILDINGS
		ROADS OR WALKS
		CURBING
		RAILROAD
		EARTH FILL
		EARTH CUT
	T☐	TELEPHONE MANHOLE
		CONTRACTORS WORK LIMIT
—F—	—EF—	FENCE
		STONE WALLS
		GRADE TO DRAIN
—SD—	—SD—	STORM DRAIN
		STORM DRAINAGE MANHOLE
		CATCH BASIN
—C—	—C—	CULVERT
	—WL—	MILL WASTE LINE
—SS—	—SS—	SANITARY SEWER LINE
		SEWER MANHOLE
—W—	—W—	WATER LINE
		GATE VALVE
—MS—		MILL WATER SUPPLY LINE
		GUARD RAIL
	—G—	GAS LINE
	—E—	ELECTRIC LINE OVERHEAD
	—T—	TELEPHONE LINE UNDERGROUND
	FD	FOUNDATION TEST BORING
	FTT	FOUNDATION TEST TRENCH
		BID ITEM NUMBER
		SUB DRAIN
	WL	WATER LEVEL AT TIME OF CONSTRUCTION
		ROCK SLOPE PROTECTION, ROCK CHANNEL PROTECTION OR ROCK PAVING
		EARTH CUT WITH ROCK SLOPE PROTECTION
		EARTH FILL WITH ROCK SLOPE PROTECTION, OR ROCK PAVING
—E—		ELECTRIC LINE UNDERGROUND
		FIRE HYDRANT

CHARLES A. MAGUIRE & ASSOCIATES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

BLACKSTONE RIVER FLOOD CONTROL
LOWER WOONSOCKET

PROJECT PLAN

BLACKSTONE, MILL & PETERS RIVERS RHODE ISLAND

DATE JUNE

SCALE 1"=300'

PLATE NO. 23

CORPS OF ENGINEERS

U. S. ARMY

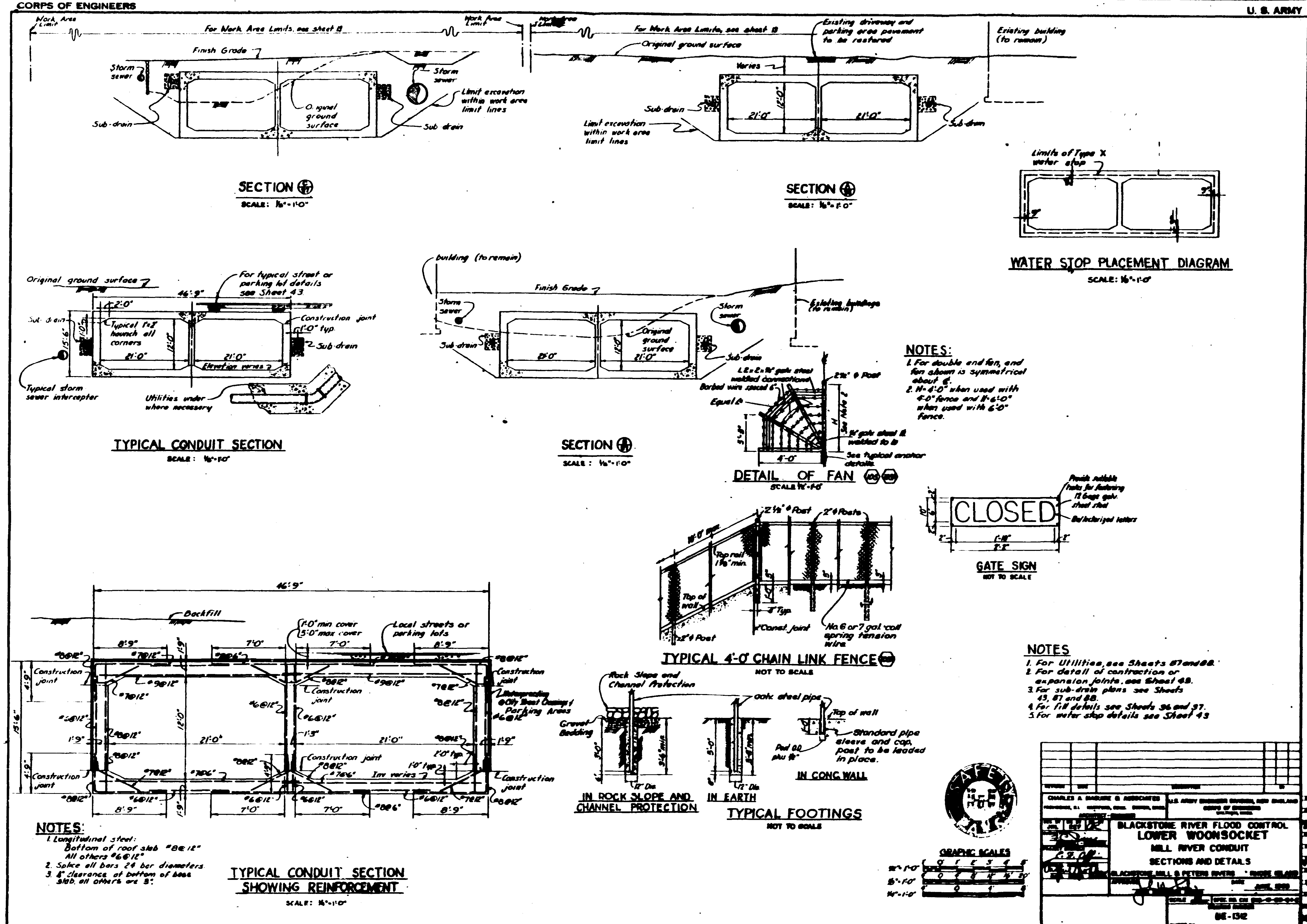
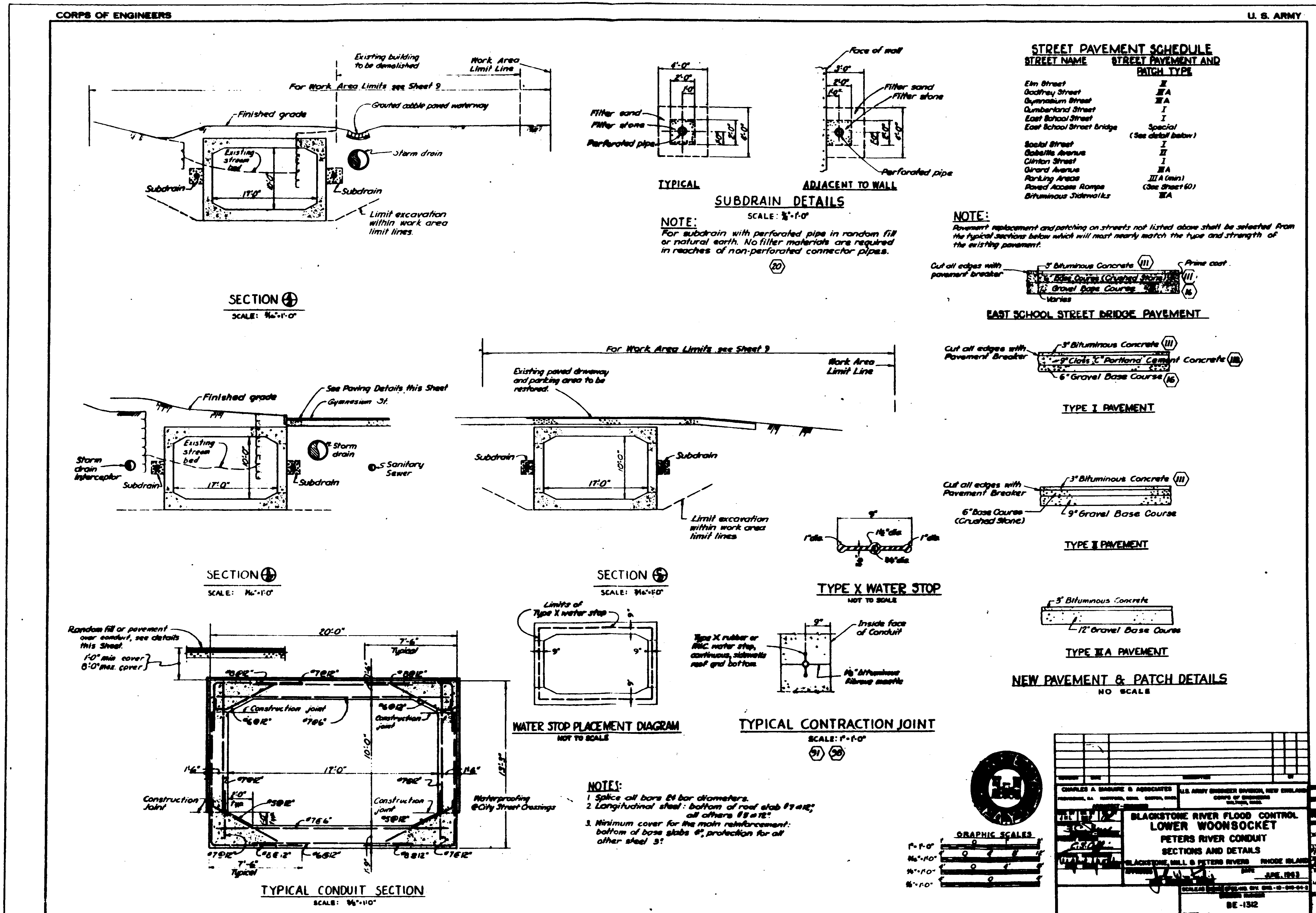
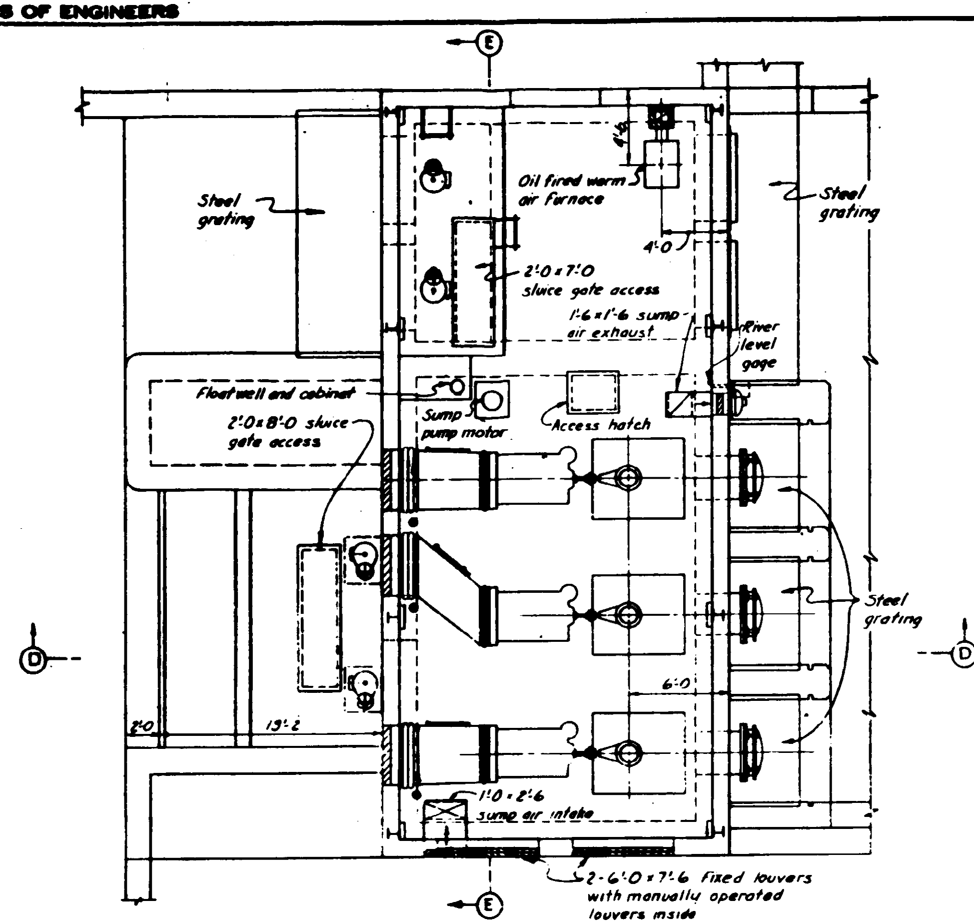


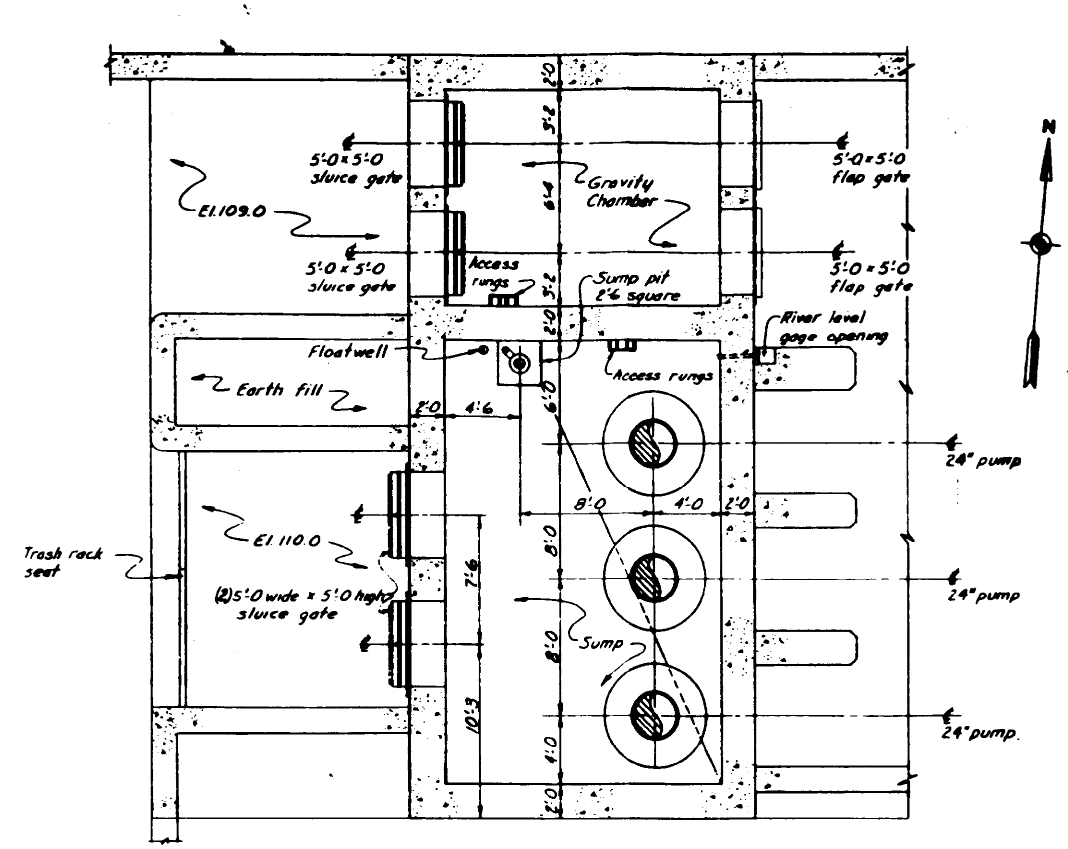
PLATE NO. 24


CORPS OF ENGINEERS
U. S. ARMY
Existing building to be demolished
Work Area Limit Line
For Work Area Limits see Sheet 9
Finished grade
Grouted cobble paved waterway
Storm drain
Existing stream bed
Subdrain
Limit excavation within work area limit lines.
SECTION
SCALE: 3/16"=1'-0"
TYPICAL
ADJACENT TO WALL
Face of wall
Filter sand
Filter stone
Perforated pipe
SUBDRAIN DETAILS
SCALE: 3/4"=1'-0"
NOTE:
For subdrain with perforated pipe in random fill or natural earth. No filter materials are required in reaches of non-perforated connector pipes.
STREET PAVEMENT SCHEDULE
STREET NAME
STREET PAVEMENT AND PATCH TYPE
Elm Street
Godfrey Street
Gymnasium Street
Cumberland Street
East School Street
East School Street Bridge
Special (See detail below)
Social Street
Gabelle Avenue
Clinton Street
Girard Avenue
Parking Areas
Paved Access Ramps (See Sheet 60)
Bituminous Sidewalks
NOTE:
Pavement replacement and patching on streets not listed above shall be selected from the typical sections below which will most nearly match the type and strength of the existing pavement.
Cut all edges with pavement breaker
3" Bituminous Concrete
Prime coat
Base Course (Crushed Stone)
Gravel Base Course
Varies
EAST SCHOOL STREET BRIDGE PAVEMENT
See Paving Details this Sheet
Gymnasium St.
Storm drain interceptor
Sanitary Sewer
Existing paved driveway and parking area to be restored.
9" Class "C" Portland Cement Concrete
6" Gravel Base Course
TYPE I PAVEMENT
6" Base Course (Crushed Stone)
9" Gravel Base Course
TYPE II PAVEMENT
TYPE X WATER STOP
NOT TO SCALE
3" Bituminous Concrete
12" Gravel Base Course
TYPE IIIA PAVEMENT
NEW PAVEMENT & PATCH DETAILS
NO SCALE
Random fill or pavement over conduit, see details this Sheet.
1'-0" min. cover
8'-0" max. cover
Typical
Construction joint
Waterproofing @ City Street Crossings
TYPICAL CONDUIT SECTION
SCALE: 3/8"=1'-0"
Limits of Type X water stop
WATER STOP PLACEMENT DIAGRAM
NOT TO SCALE
Type X rubber or P.V.C. water stop, continuous, sidewalls roof and bottom.
Inside face of Conduit
1/2" bituminous fibrous mastic
TYPICAL CONTRACTION JOINT
SCALE: 1"=1'-0"
NOTES:
1. Splice all bars 24 bar diameters.
2. Longitudinal steel: bottom of roof slab #7 @ 12", all others #5 @ 12".
3. Minimum cover for the main reinforcement: bottom of base slabs 6", protection for all other steel 3".
GRAPHIC SCALES
CHARLES A. MAGUIRE & ASSOCIATES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
BLACKSTONE RIVER FLOOD CONTROL
LOWER WOONSOCKET
PETERS RIVER CONDUIT
SECTIONS AND DETAILS
BLACKSTONE, MILL & PETERS RIVERS
RHODE ISLAND
JUNE, 1963
BE-1312



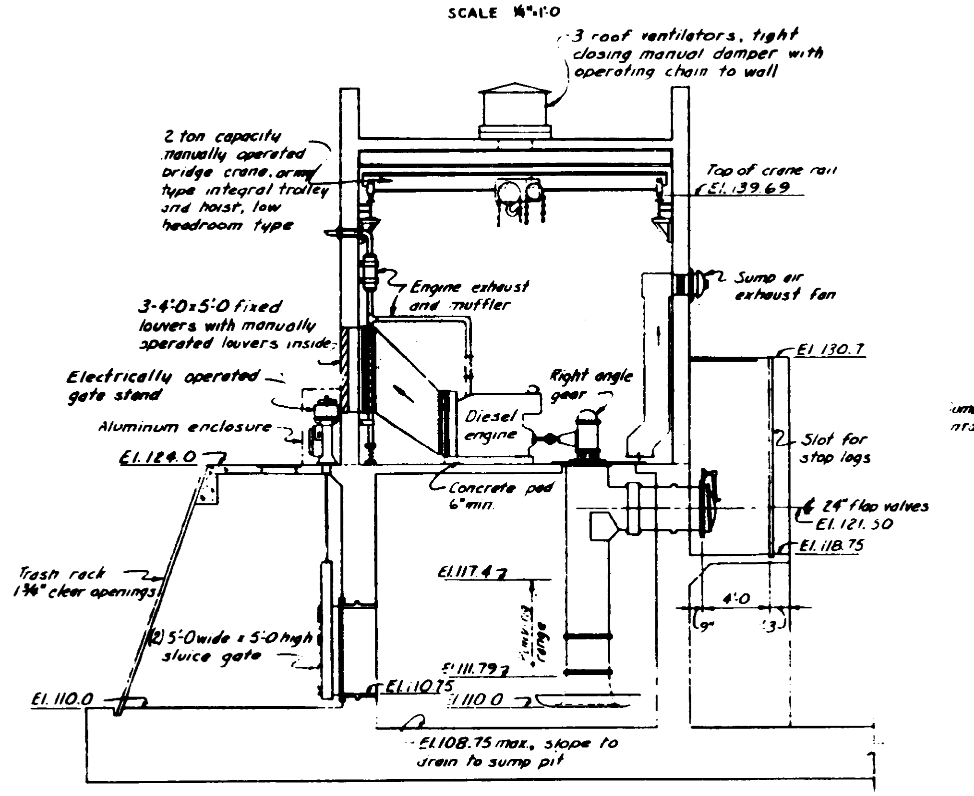
OPERATING FLOOR PLAN

SCALE ¼"=1'-0



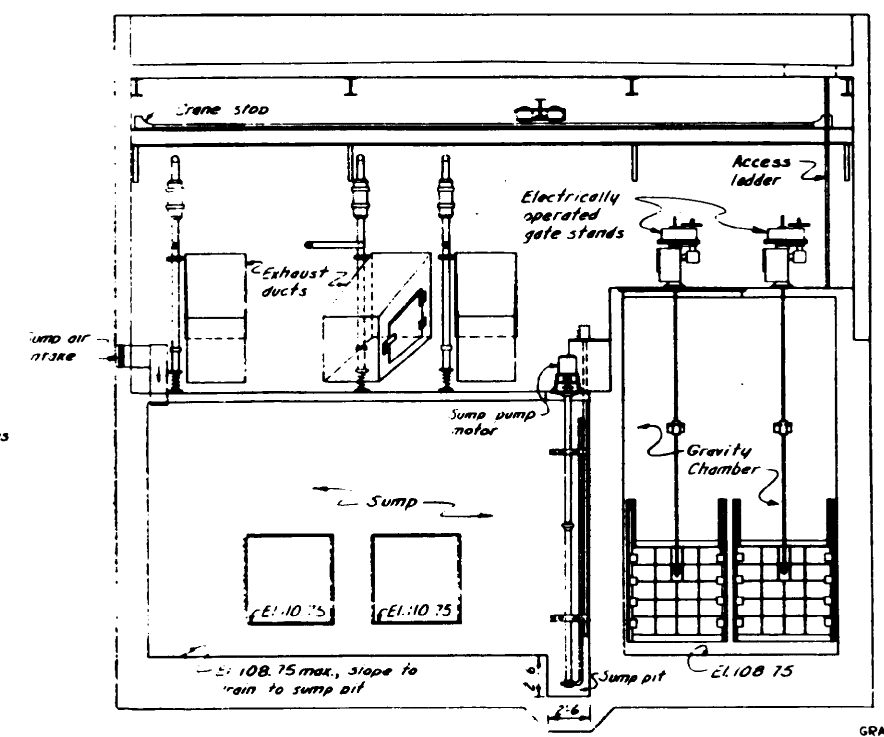
SUMP PLAN

SCALE ¼"=1'-0



SECTION D-D

SCALE: ¼"=1'-0



SECTION E-E

SCALE: ¼"=1'-0

GRAPHIC SCALE

¼"=1'-0 0 4' 8'

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
PROVIDENCE, R.I. HARTFORD, CONN. BOSTON, MASS.
ARCHITECT - ENGINEER

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

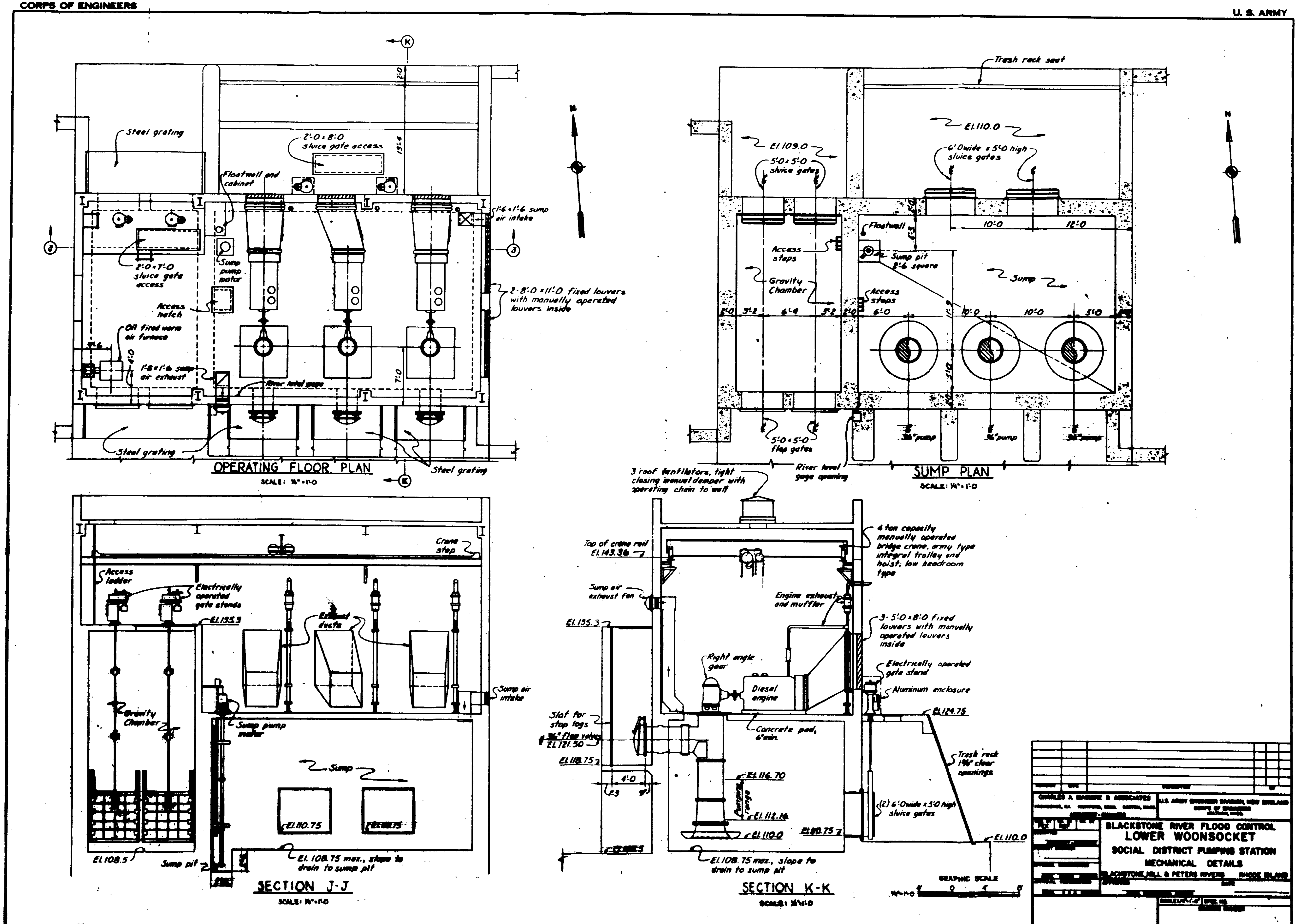
DES. BY PEK | DR. BY REF | CK. BY

SUBMITTED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, E & S DIVISION

BLACKSTONE RIVER FLOOD CONTROL
LOWER WOONSOCKET
HAMLET DISTRICT PUMPING STATION
MECHANICAL DETAILS
BLACKSTONE, MILL & PETERS RIVERS RHODE ISLAND

APPROVED
CHIEF, ENGINEERING DIVISION
DATE

SCALE 1/4"=1'-0" | SPEC. NO.
DRAWING NUMBER
SHEET


Steel grating
2'-0 x 8'-0 sluice gate access
Floatwell and cabinet
1'-6 x 1'-6 sump air intake
2'-0 x 7'-0 sluice gate access
Sump pump motor
Access hatch
2-8'-0 x 11'-0 fixed louvers with manually operated louvers inside
Oil fired warm air furnace
1'-6 x 1'-6 sump air exhaust
River level gage
Steel grating
OPERATING FLOOR PLAN
SCALE: 1/8" = 1'-0
Trash rack seat
El. 110.0
El. 109.0
5'-0 x 5'-0 sluice gates
6'-0 wide x 5'-0 high sluice gates
Floatwell
Access steps
Sump pit 2'-6 square
Gravity Chamber
Sump
36" pump
5'-0 x 5'-0 flap gates
River level gage opening
SUMP PLAN
SCALE: 1/8" = 1'-0
Crane stop
Access ladder
Electrically operated gate stands
El. 135.3
Exhaust ducts
Sump air intake
Gravity Chamber
Sump pump motor
Sump
El. 110.75
El. 108.5
Sump pit
El. 108.75 max., slope to drain to sump pit
SECTION J-J
SCALE: 1/8" = 1'-0
3 roof ventilators, tight closing manual damper with operating chain to wall
Top of crane rail El. 143.36
4 ton capacity manually operated bridge crane, army type integral trolley and hoist, low headroom type
Sump air exhaust fan
Engine exhaust and muffler
El. 135.3
3-5'-0 x 8'-0 fixed louvers with manually operated louvers inside
Right angle gear
Diesel engine
Electrically operated gate stand
Aluminum enclosure
El. 124.75
Slot for stop logs
36" flap valve El. 121.50
Concrete pad, 6" min.
El. 118.75
El. 116.70
Trash rack 1 3/4" clear openings
El. 112.16
El. 110.0
(2) 6'-0 wide x 5'-0 high sluice gates
El. 110.0
El. 108.75 max., slope to drain to sump pit
SECTION K-K
SCALE: 1/8" = 1'-0
GRAPHIC SCALE
CHARLES A. MAGUIRE & ASSOCIATES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS
BLACKSTONE RIVER FLOOD CONTROL
LOWER WOONSOCKET
SOCIAL DISTRICT PUMPING STATION
MECHANICAL DETAILS
BLACKSTONE, MILL & PETERS RIVERS
RHODE ISLAND

LOG OF RADIO REPORTS - FLOOD CONTROL DAMS

WEST HILL DAM

Line	ITEM	1/22/65												Line
1	Time of Observation	0800												1
2	Precipitation (last 24 hours)	0												2
3	Form of Precipitation	—												3
4	Present Weather	clear												4
5	Pool Stage	2.25												5
6	Tendency	Steady												6
7	Gate Openings	3'-0-3'												7
8	Tailwater Gage	1.47												8
9	Outflow	24												9
10	INDEX POINTS NORTHBRIDGE	2.9												10
11														11
12														12
13														13
14														14
15														15
	REMARKS													
	NED FORM APR 61 477													

SAMPLE

SHEET NO. -1

NED FORM MAR63 503

REGULATION OF WOONSOCKET FALLS DAM AND WEST HILL DAM & RESERVOIRS

LOG OF REPORTS AND INSTRUCTIONS

DATE AND TIME OF REPORT	WOONSOCKET FALLS DAM												WEST HILL RES.											BLACKSTONE RIVER AT NORTHBRIDGE, USGS.			BLACKSTONE RIVER AT WOONSOCKET, USGS.			RIVER AT					
	RES POOL		GATE OPENING								OUTFLOW		RES POOL		GATE OPENING			OUTFLOW		PRECIPITATION															
	HOUR	STAGE	1	2	3	4	[illegible]	[illegible]	[illegible]	[illegible]	T.W.	C.F.S.	HOUR	STAGE	1	2	3	T.W.	C.F.S.	LOCATION	HOUR	INCHES INC.	INCHES ACC.	HOUR	STAGE	C.F.S	HOUR	STAGE	C.F.S	HOUR	STAGE	C.F.S	HOUR	STAGE	C.F.S
4/1/62																				Woonsocket	0700	–	1.05	0700	5.1	970									
0815	0800		0	0	0	0							0800	5.83	3	0	3		80	Mendon	0800	–	1.32	0800	5.6	1330	0800	4.95	2470						
																				Milford	0800	–	1.15												
	(Instr: Call back @ 2" Rainfall or stage Northbridge 6.0' or Woonsocket 7.0')																																		
1615	1600		0	0	0	0							1600	6.15	3	0	3	2.7	216	Woonsocket	1600	.70	1.75	1600	6.2	1630	1600	5.35	2870						
																				Mendon	1600	.60	1.92												
																				Milford	1600	.50	1.65												
	(Instr: Regulate West Hill to 0-0-0.5' Call back @ 2.5" Rainfall or stage Northbridge & Woonsocket 7.0')																																		
													1615	6.15	0	0	.05	2.7	22	Woonsocket	0800	.40	2.15												
4/2/62	0800	2.0	1	0	0	1							0800	7.31	0	0	.05	1.60	24	Mendon	0800	.40	2.32	0800	7.3	2300	0800	5.5	3030						
0820																				Milford	0800	.50	2.15												
	(Instr: Call back @ 3.0" Rainfall or Stage Northbridge 8.0' or Woonsocket 7.0')																																		
1610	1600	2.25	1	1	0	1							1600	8.7	0	0	.05	1.63	26	Woonsocket	1545	.05	2.2	1600	8.0	2720	1600	5.8	3320						
																				Mendon	1600	.08	2.4												
																				Milford	1545	.15	2.30												
	(Instr: Call back @ 3.0" Rainfall or stage Northbridge 9.0' or Woonsocket 7.0')																																		
4/3/62	0800	2.1	1.5	1	0	1							0800	12.9	0	0	0.5	1.96	31	Storm Over				0800	7.1	2180	0800	6.2	3800						
0810																																			
	(Instr: Call back @ stage Woonsocket 7.0' or 1600)																																		
1615	1600	2.0	1	1	0	0							1600	14.02	[illegible]	0	.05	[illegible]	33					1600	5.7	1390	1600	5.5	3030						
	(Instr: Regulate West Hill to [illegible] Call back @ 4/4 0800)																																		
4/4/62													1630	14.02	1	1	1		[illegible]																
0815	0800	1.6	1	0	0	0							0800	13.3	1	1	1	[illegible]	186					0800	5.2	1090	0800	4.6	2120						
	(Instr: Regulate West Hill to 2-2-2 Call back @ 1600)																																		
													0830	3.3	2	2	2		348																
1610	1600	1.2	0	0	0	0							1600	10.7	2	2	2	3.01	324					1600	4.6	760	1600	3.4	1100						
	(Instr: Call back [illegible] 4/5 0800)																																		
4/5/65	0800	–	0	0	0	0							0800	8.2	2	2	2		276																
0815	(Instr: Regulate to normal gate setting 3-0-3)																																		
													0830	8.2	3	0	3		268																
	End of Operation																																		

SAMPLE

SHEET NO. -2

GATE OPERATION RECORD

WEST HILL RESERVOIR April MONTH 1962 YEAR

DATE	HOUR	RES. STAGE Feet	GATE OPENING IN FEET* #1	#2	#3						OUTFLOW C.F.S. BEFORE	AFTER	REMARKS
4/1/62	1200	6.43	3	0	3						—	224	
	1220	6.43	0	0	0.5						224	22	
4/2/62	1300	13.07	1	0	1						32	124	
4/3/62	0830	14.11	1.5	1.5	1.5						128	288	
	1345	14.10	2.0	1.5	2.0						288	348	
	1500	14.02	2.0	2.0	2.0						348	378	
4/5/62	0830	9.05	2.5	2.5	2.5						294	366	
	1600	8.15	3	1	3						336	312	
4/6/62	0830	6.50	3	2.5	3						252	304	
	1500	4.91	3	0	3						264	184	
4/7/62	0830	4.19	3	0	3						174		
	End of Operation												

SAMPLE

*Indicate full opened gate by "F"

SIGNED ____________________
OPERATOR

DATE ____________________

lution (i.e., vehicle emissions systems,

APPENDIX A

RESERVOIR REGULATION

WEST HILL DAM AND RESERVOIR

APPENDIX A

RESERVOIR REGULATION

TABLE OF CONTENTS

APPENDIX A

LIST OF PLATES

APPENDIX A

RESERVOIR REGULATION

1. ORGANIZATION

The Reservoir Regulation Section is responsible for regulation of the flood control reservoirs in the New England area. In the New England Division, the Hydrology & Hydraulics Branch of the Engineering Division also functions as the Reservoir Regulation Section. In addition to its regular flood control duties, the Reservoir Regulation Section is also responsible for (a) monthly reports on reservoir regulation; (b) continuing studies of regulation procedures; (c) analyses of actual flood operations; (d) the establishment of a data-gathering and reporting network; (e) maintenance of hydrologic equipment; and (f) the training of personnel. The supervision of routine operations and maintenance activities comes under the jurisdiction of the Maintenance Branch of the Operations Division. An organization chart for reservoir regulation in the New England Division is shown on plate A-1.

The Reservoir Regulation Section is subdivided into basin units, each of which is responsible for receiving routine hydrometeorological reports and directing reservoir regulation within an assigned river basin. Each unit consists of basin and project regulators who receive reports and issue regulation instructions either from NED headquarters during normal work-hours or from their homes during nonwork-hours. Whenever emergency conditions exist, the RRS mobilizes and staffs NED headquarters on a 24-hour basis.

2. INSTRUCTIONS TO OPERATORS

All instructions to operators for regulation of the flood control reservoirs are given directly by the Reservoir Regulation Section with advisories to the Division Engineer and the Chiefs of the Engineering and Operations Divisions, and the Disaster Control Center. When a flood control dam operator is unable to communicate with the RRS and the circumstances require immediate action, the operator has full authority and responsibility to promptly regulate the reservoir in accordance with procedures described in paragraph 15, "Emergency Operating Procedures."

3. COMMUNICATIONS

All communications between the flood control dam operator and RRS are made via the NED radio network whenever the section is staffed in NED headquarters. During nonworking hours, reports and regulation instructions are issued by telephone to and from the homes of RRS personnel. A telephone directory is maintained and issued by the Reservoir Regulation Section for its specific use during flood operations. Included in the directory are names, addresses and telephone numbers of local observers. In the event of failure of the NED radio network and telephone service, emergency communications will be attempted through State Police and Civil Defense radio facilities.

4. PRECIPITATION REPORTING NETWORK

In the Blackstone River basin reports of precipitation data are primarily used for the purpose of alerting regulation personnel and to provide a basis for estimating the magnitude of flood runoff. The River Forecast Center at Windsor Locks, Connecticut receives reports from the U. S. Weather Bureau precipitation stations in the Blackstone River basin which are also made available to the RRS.

Precipitation reports from the USWB are supplemented by precipitation data furnished by the West Hill Dam operator who receives reports directly from the stations shown below. Observers notify the operator whenever 1 inch of rainfall has been recorded at their respective stations.

Whitinsville Water Company	Northbridge, Mass.
Uxbridge Water Department	Uxbridge, Mass.
USWB Station (private home)	Mendon, Mass.
Woonsocket Sewer Plant	Woonsocket, R. I.

Locations of the USWB and NED precipitation network are shown on plate 1 of the main report.

5. RIVER REPORTING NETWORK

The river reporting network for the Blackstone River basin consists of 8 stations, 5 in Massachusetts and 3 in Rhode Island. Locations of the gaging stations are shown on plate 1 of the main report are described below:

Massachusetts

USGS gage at Kettle Brook	Worcester
Staff gage at Webster Street bridge	Worcester
USGS gage on Blackstone River	Northbridge
Staff gage at Loumac Corp.	Millville
USGS gage on West River below West Hill Dam	Uxbridge
Staff gage on West River at Waucantuck Mills	Wheelockville

Rhode Island

USGS gage on Branch River near Stamina Mills	Forestdale
Staff gage on Blackstone River at Woonsocket Falls Dam	Woonsocket
USGS gage on Blackstone River	Woonsocket

The gages at Worcester, Massachusetts indicate the streamflows in the upper Blackstone River basin; gages at Northbridge, Millville and Wheelockville indicate streamflows in the middle basin; and gages at Forestdale and Woonsocket indicate flows in the lower basin. Whenever high river stages are anticipated in the basin, the operator makes arrangements with local observers to report pertinent information.

6. WEATHER AND RIVER FORECASTS

a. Precipitation forecasts. In addition to the normal periodic weather forecasts, quantitative precipitation forecasts prepared by the USWB are received daily over the Massachusetts Weather Teletype Network by the RRS. Supplemental weather information and forecasts are made available upon request to the U. S. Weather Bureau offices at Boston, Massachusetts and Windsor Locks, Connecticut.

b. USWB river forecasts. The U. S. Weather Bureau River Forecast Center at Windsor Locks, Connecticut is responsible for preparing and disseminating flood forecasts to the public for the Blackstone River basin. The River Forecast Center also prepares and transmits by teletype to the RRS biweekly headwater advisory forecasts, indicating the amount of 12-hour rainfall necessary to produce flood conditions at Woonsocket, Rhode Island in the Blackstone River basin.

c. USCE flood forecasts. Methods for estimating flood peak forecasts have been developed for Corps of Engineers use only. Curves of total rainfall versus peak discharge at Northbridge and Woonsocket have been determined from available information. These curves will be checked with future data and modified, if necessary, to improve the correlation. Curves for forecasting peak flows at Northbridge, Massachusetts and Woonsocket, Rhode Island are shown on plate A-3.

7. REPORTS

a. Weekly reports. The flood control dam operator makes a routine report by radio or telephone to the RRS at 0815 each Friday. This report assures continuous contact between the operating personnel and the RRS and also serves as a communications test. The report includes the preceding 24-hour precipitation and current weather data, reservoir stage and regulation data, river conditions at index stations and other miscellaneous information. A sample of the completed form is shown on sheet 1.

b. Alerting reports. The alerting report will consist of rainfall within the basin and stages at the reservoir and index stations. The flood control dam operator at West Hill will immediately notify the RRS whenever any of the following conditions occur:

(1) Precipitation. Occurrence of 1 inch during a 24-hour period at any precipitation station within the network.

(2) Reservoir stage. Whenever a stage of 5 feet (and rising) is reached at West Hill Reservoir.

(3) River stage. Whenever the river stage at Northbridge reaches 5 feet and rising, and/or the stage at Woonsocket reaches 7 feet and rising.

(4) Unusual conditions. Any unusual local condition such as difficulty with gates, ice, excessive debris, etc.

c. Flood reports. Supplemental radio and telephone reports are made to the RRS by the flood control dam operator if heavy rainfall continues or if it appears that flood conditions might develop in the basin as the result of melting snow, heavy localized rainfall, dam failures, etc. Time and frequency of these reports are dependent upon the severity of conditions and specific instructions from the RRS. Sheet 2 shows a typical log of reports which indicates the data to be included in reports by the flood control dam operator during flood periods. Insofar as practicable, the following information is included in the flood report to the RRS.

(1) Precipitation at dam. The total amount of precipitation which has fallen up to the time of reporting and several intermediate amounts with the times of observation.

(2) Reservoir stage. The pool stage at the time of reporting and several previous readings with the corresponding times to determine rate of rise of the pool and to define the inflow hydrograph (accurate simultaneous readings of both stage and time are very essential to facilitate computations made by the RRS).

(3) Gate position. Gate openings and discharges at time of reporting and beginning of the storm.

(4) Precipitation reports from observers. Precipitation reports received from cooperative observers.

(5) River stages. River stages at time of reporting at Northbridge, Massachusetts and Woonsocket, Rhode Island and other river gages if requested by RRS.

(6) Snow cover. General snow cover which may affect runoff conditions throughout the basin.

(7) Miscellaneous data. Any other information which might be pertinent.

d. Special reports. A special report is submitted whenever unusual circumstances occur during a flood or if a special report is requested by the RRS. The report may be written in longhand and should describe the subjects outlined below if appropriate.

(1) Observations at dam. The flood control dam operator makes general observations of conditions occurring at the outlet works as listed below. Observations are entered in the log book at the dam. If possible, photographs are taken of any unusual conditions noting date, time, reservoir gage heights and position of the gates.

(a) Intake and portal. Extent and action of eddies and waves in the vicinity of the conduit intakes and portals.

(b) Outlet and spillway discharge channels. Extent and action of turbulence or eddies downstream of the spillway and outlet works.

(c) Ice and debris. Effect on flow through the gates due to an accumulation of ice or debris at the intake.

(d) Gates. The pool elevation and position of the gates at which vibration may develop.

(e) Other. Any other unusual hydraulic phenomena that may occur.

(2) Observations at control points. During periods of reservoir regulation, particularly while emptying the reservoir, reconnaissance of the river is made by the flood control dam operator to obtain further data on the safe channel capacity of the Blackstone River through principal damage areas. Critical stages at damage points are correlated with concurrent stage at the nearest gaging station to obtain corresponding discharge.

8. SPECIAL ADVISORIES

In accordance with regulations set forth in EM 500-1-1, Emergency Flood Control Activities, special advisories from RRS on flood potential and progress of all threatening storms are submitted to the Division Engineer, Disaster Control Center and Chiefs, Engineering Division, Planning and Reports Branch and Operations Division.

9. MAINTENANCE OF LOG

All reports, instructions, records of unusual circumstances at the dam, and information pertinent to regulation of the reservoir is entered in the logs. A log is maintained by both the flood control dam operator and the Reservoir Regulation Section.

10. GATE OPERATION RECORD

All gate operations are carefully noted on NED Form 90, a sample of which is shown on sheet 3, and submitted monthly with recorder charts of reservoir stages. All operations are noted regardless of duration of the change in gate position. The report includes date and time of day, gate opening, reservoir gage height and reason for operation.

11. RESERVOIR REGULATION - NORMAL PERIODS

The outlet gates at West Hill Dam will be maintained at gate settings of 3'-0'-3' (full opening 5 feet) in order to restrict outflow in the event of a flash flood. A winter pool has not been maintained in West Hill Reservoir, but will be if future experience shows submergence of the gates is necessary.

12. RESERVOIR REGULATION - FLOOD PERIODS

a. <u>General</u>. Regulation of flow from West Hill Reservoir is initiated for specific river stages on the Blackstone River or heavy rainfall over the basin. Regulation may be considered in three phases during the course of a flood: Phase I, the appraisal of storm and river conditions during the development of the flood leading to the initial regulation; Phase II, regulation during the flood period; and Phase III, emptying the reservoir following downstream recession of the flood. The SOP for regulating the reservoir is shown on plate A-2.

b. <u>Phase I - initial regulation of flow</u>. Gates operations at West Hill Dam are initiated for river stages on the Blackstone River and also for rainfall over the basin. Index stations for regulation of the reservoir where stage-discharge and stage-damage relationships have been established are as follows.

Index Location	Damage Stage	Stage for Initiating Regulation	Regulation Required
West Hill Dam		7 feet and rising	1.0-0.0-1.0
Northbridge USGS Gage (Telemark)	7 feet (2,130 cfs)	6 feet (1,570 cfs)	0.0-0.2-0.0
Woonsocket USGS Gage	9 feet (7,190 cfs)	6 ft (3,580 cfs) when river is predicted to exceed damage stage	0.0-0.2-0.0

Experience indicates that 2 inches of rainfall over the basin in 24 hours will produce a moderate rise in river stages depending on antecedent ground conditions. Therefore, initial regulation of the reservoir is also considered necessary whenever the following rainfall has been recorded at any index precipitation station in the basin within a 24-hour period.

24-HOUR RAINFALL
(Inches)

Antecedent Conditions		
Snow Covered, West or Frozen	Dry	Regulation Required
2.0	3.0	Gates to be set at 1'-0'-1'
3.0	4.0	Gates to be set at 0'-0'-0.2' (minimum discharge = 10 cfs)

c. Phase II - continuation of regulation. During this phase of a flood, outflow from the reservoir is regulated to alleviate or reduce, as far as practicable, downstream flood damages. If the gates are completely closed, they remain in this position until the final phase of operation is initiated and emptying of the stored runoff may begin. If some outflow is being released, further gate operations may be necessary as the reservoir rises in order to maintain nondamaging flows. Another important regulation activity during this period is the collection of hydrologic and hydraulic data. The most important information to be obtained is: (1) precipitation amounts throughout the entire Blackstone River basin and at as many surrounding locations outside the watershed as possible; (2) snow cover and water content in case of a spring flood; (3) stage and discharge values at downstream control points in the Blackstone River; and (4) any other pertinent rainfall and runoff information which will assist in the regulation of the reservoir.

d. Phase III - emptying the reservoir. Following recession of the flood on the Blackstone River, the reservoir is emptied as rapidly as possible. Stored flood water will be released in accordance with instructions issued by the Reservoir Regulation Section. Normally, RRS will issue instructions to start emptying the reservoir as soon as it is expected that stages at Northbridge and Woonsocket have crested and are receding. If this storage in the reservoir is less than 75 percent of the total, emptying will be delayed until the Blackstone River has receded below flood stage. If more than 75 percent storage has been used, outflow may be initiated while the Blackstone River is still above flood stage. The outflow will be controlled, however, to permit continued recession of the main river stages.

The maximum allowable release from the reservoir will be between 300 to 400 cfs. This channel capacity was determined from observed discharge conditions at Waucantuck Mills dam, located about 2 miles downstream of the dam. Discharge will be increased in steps of 100 cfs or less at intervals of 2 hours or more until safe channel capacity has been reached. Until experience has been attained, the time between gate changes should be sufficient to assure that increased discharge from the West River has reached the Blackstone River and no flood problems have been created.

If the Blackstone River has crested at Woonsocket at less than flood stage (9.0 feet) RRS will issue instructions to start emptying the reservoir immediately. Guide curves for evacuating flood storage are shown on plate A-4. Secondary river rises during Phase III, due to either additional rainfall or snowmelt, may result in the regulation procedure reverting to Phase I.

e. Spillway discharge. Ordinarily during a major flood the gates will not be opened to avoid spillway discharge. Surcharge storage above the elevation of the spillway crest will be utilized whenever the downstream channel capacity continues to be exceeded by runoff from uncontrolled areas. However, when the pool rises to elevation 272 (8 feet above spillway crest) all gates will be fully opened. Whenever the pool rises above elevation 269 feet msl (guide taking line) all residents within the reservoir area will be so notified. Police and/or officials of communities downstream on the Blackstone River that may be affected during an extreme flood will also be advised immediately of impending conditions.

13. EXTRAORDINARY FLOOD CONDITIONS

It is conceivable that extraordinary and unpredictable flood conditions may arise, such as dam or bridge failures, highway or railroad washouts, ice jams or debris deposits. Since the prime purpose of the reservoir is to prevent further damage, regulation during such unusual conditions may not follow previously described rules but will be governed by the urgency of the circumstances. The RRS will be notified immediately of any unusual incident so that prompt action may be taken and the gates operated to provide maximum protection.

14. REGULATION WITH FAILURE OF COMMUNICATIONS

If the flood control dam operator is unable to communicate with the RRS by normal or emergency methods and conditions develop which appear to warrant regulation, he will operate the gates in accordance with instructions contained in paragraph 15, Emergency Operating Procedure. However, possession of the instructions contained in this manual does not relieve the operator of his responsibility for continued efforts to communicate with the Reservoir Regulation Section. In cases of extreme emergency, the operator shall attempt to communicate with the RRS through the Massachusetts and/or Rhode Island State Police and the Office of Civil Defense Mobilization radio networks. It should be emphasized that whenever communications fail, or due to lack of adequate reports, it is impossible to fully appraise the runoff from an intense storm, it is preferable to immediately restrict or completely stop the reservoir discharge than to delay regulation and actually contribute to downstream flood conditions.

15. EMERGENCY OPERATING PROCEDURE (EOP)

When unable to contact the RRS and flood conditions develop, the flood control dam operator has full authority to act promptly in accordance with instructions contained herein regarding the closure of gates. However, emptying the reservoir will not be initiated until contact has been established with the RRS.

All gates will be closed immediately to minimum openings of 0-0-0.2' (10 cfs ±) whenever any of the following conditions occur.

a. Rainfall. Whenever 2.5 inches of rain has fallen at any precipitation station in the Blackstone River basin within a 24-hour period.

b. River stages. Whenever river stages at the following index stations reach the indicated level.

Index Station	Stage for Complete Closure of Gates
West Hill Pool	7.0 feet and rising
Northbridge (USGS Gage)	6.0 feet and rising
Woonsocket (USGS Gage)	7.5 feet and rising

The EOP is shown on plate A-2.

16. COOPERATION WITH DOWNSTREAM WATER USERS

It is the policy of the Corps of Engineers to cooperate, whenever possible, with downstream water users and other interested parties or agencies. The flood control dam operator may be requested by downstream users to deviate from normal regulations for short periods of time. Whenever a request for such modification is received, the operator ascertains the validity of the request and obtains assurances from other downstream water users that they are agreeable to the proposed operations. The operator then relays the information to the RRS and requests instructions.

17. SNOW SURVEYS

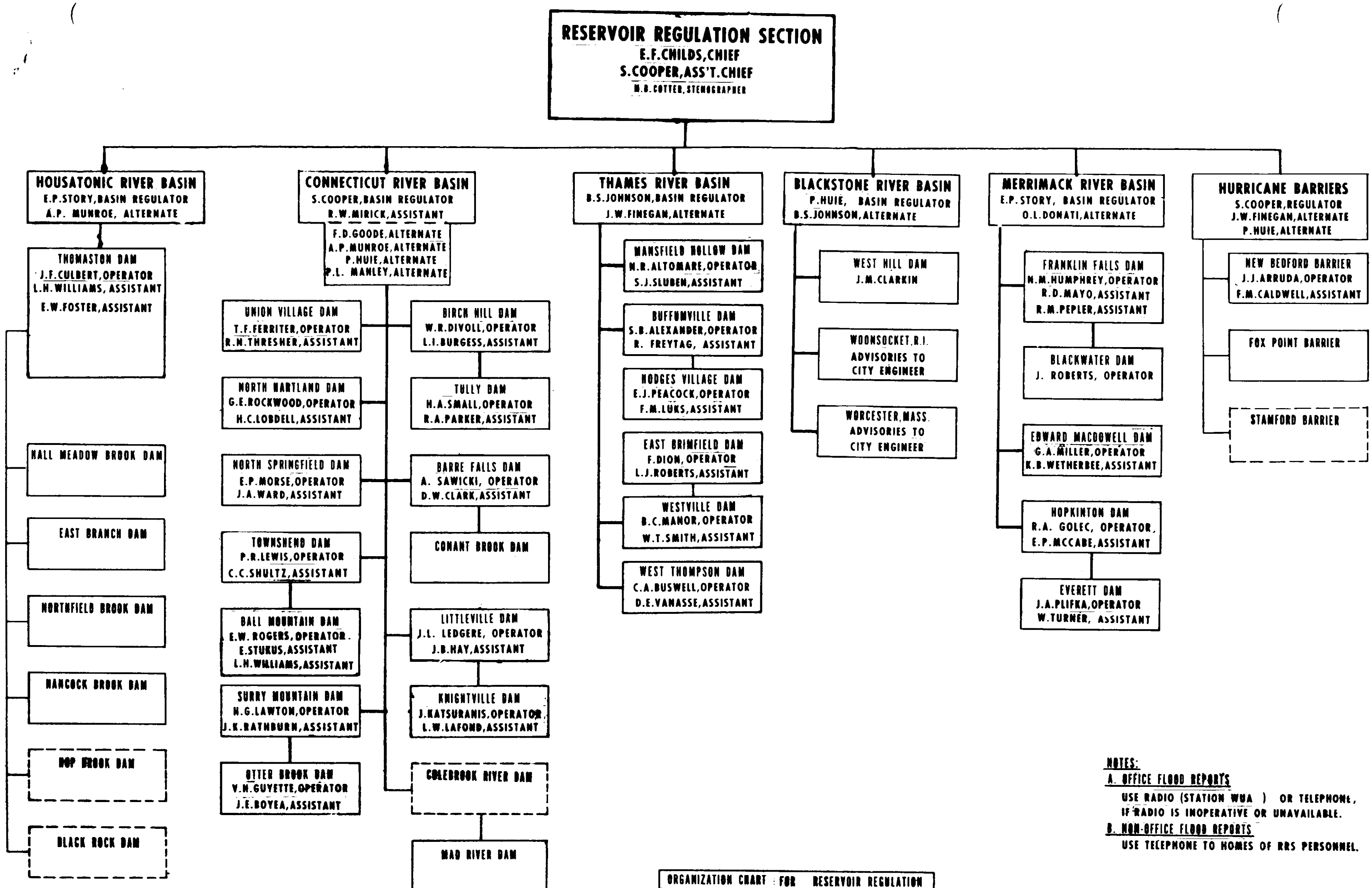
Snow courses have been established at selected locations within the reservoir watershed and are shown on plate 1 of the main report. Weekly surveys are made by the flood control dam operator during the winter and early spring to determine the depth of snow and its equivalent water content. Dates for surveys are determined each year by the RRS so as to correspond with monthly bulletins of the U. S. Geological Survey.

18. ABSENCE FROM DAM

Whenever the flood control dam operator expects to be absent overnight from the dam, approval is obtained from RRS. The operator in charge at Buffumville Dam (Thames River basin) regulates West Hill Dam when the West Hill operator is absent.

19. FUTURE STUDIES

Post flood studies will be made of each period of reservoir regulation to determine efficiency of the communications and reporting networks, the applicability of regulation guides including stage-discharge relationships, discharge correlations and flood reductions at damage centers.



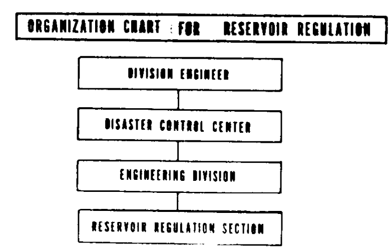
NOTES:

A. OFFICE FLOOD REPORTS

USE RADIO (STATION WUA) OR TELEPHONE, IF RADIO IS INOPERATIVE OR UNAVAILABLE.

B. NON-OFFICE FLOOD REPORTS

USE TELEPHONE TO HOMES OF RRS PERSONNEL.



ORGANIZATION CHART

RESERVOIR REGULATION SECTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

MARCH 1966

STANDARD OPERATING PROCEDURE (S.O.P.)

WEST HILL DAM & RESERVOIR

PHASE		BASIN PRECIPITATION RAINFALL - INCHES ANTECEDENT CONDITIONS		BLACKSTONE RIVER INDEX STATION (STAGE IN FEET)		WEST HILL RESERVOIR	REGULATION INSTRUCTIONS
		SNOW COVERED WET OR FROZEN	DRY	NORTHBRIDGE MASS. d.a. (139 Sq.Mi)	WOONSOCKET R.I. d.a. (416 Sq.Mi)	STAGE IN FEET	GATE SETTINGS
PHASE I APPRAISAL	ALERT	1.0	1.0	5.0 (970 c.f.s.)	7.0 (4720 c.f.s.)	5.0 and rising	NORMAL SETTING 3-0-3
	CRITICAL	2.0	3.0	6.0 (1570 c.f.s.)	8.0 (5920 c.f.s.) Projected river stage in 18 hrs.	12.0	RESTRICT OUTFLOW 1-0-1
PHASE II	FLOOD CONDITION	3.0	4.0	7.0 (2130 c.f.s.)	9.0 (7190 c.f.s.) Projected river stage in 18 hrs.	———	0-0-0.2 Min. opening 10 c.f.s.
PHASE III RECESSION	EVACUATION	STORM HAS ABATED		FOR ALLOWABLE RELEASES FROM WEST HILL DAM CONSULT GUIDE CURVES PLATE NO. A-4 MAX. ALLOWABLE DISCHARGE FROM WEST HILL DAM = 400 c.f.s.			
	POST OPERATION						NORMAL SETTING 3-0-3

DUTIES DURING EACH PHASE

FLOOD CONTROL DAM OPERATOR (FCDO)

PHASE I

1. Collect & transmit to RRS rainfall and stage data.
2. Operate according to instructions from RRS.

PHASE II

1. Close to minimum settings upon instructions from RRS.
2. Note all unusual conditions at dam, downstream channels and index stations.
3. Collect & transmit rainfall and stage data at minimum 3-hr. intervals or as directed by RRS.

PHASE III

1. See Phase II, step 3.
2. Reconnoiter flood plain and note conditions.
3. Report to RRS for further instructions.

PROJECT REGULATOR

PHASE I

1. Compile data.
2. Coordinate next transmission.
3. Restrict outflow to maintain safe channel capacity. on the West & Blackstone Rivers.
4. Inform Basin Regulator of actions.

PHASE II

1. Continue regulation instructions to FCDO.
2. Consult with Basin Regulator to analyze severity of flood.
3. Relay to FCDO any special instructions recommended by Basin Regulator.

PHASE III

1. Collect data from FCDO.
2. Check Guide Curves for allowable releases (Plate No. A-4).
3. Consult with Basin Regulator.
4. Relay instructions to FCDO.

EMERGENCY OPERATION PROCEDURE (E.O.P.)

(to be followed when contact cannot be made with RRS)

WEST HILL DAM & RESERVOIR

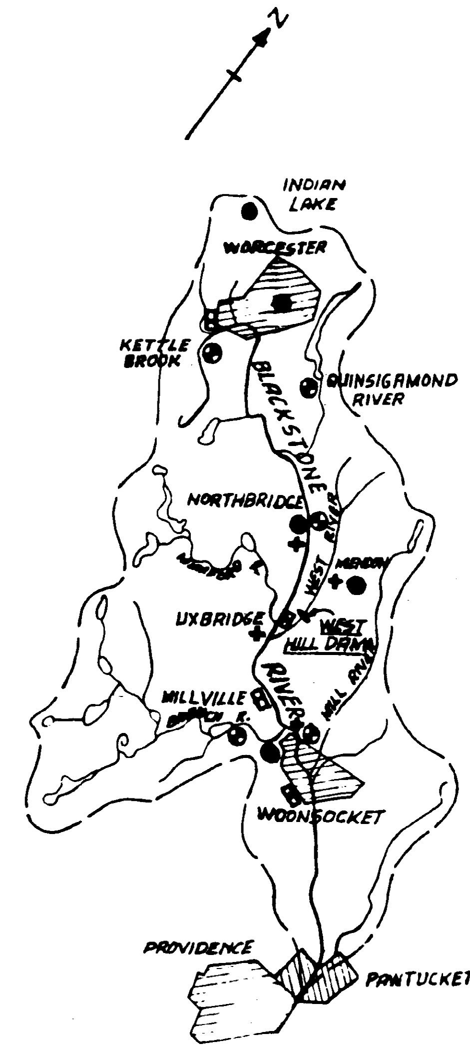
The West Hill Dam Operator is responsible for complete closure of gates (min. opening 10 cfs) in accordance with the following:

a. Rainfall - 2.5 inches has fallen in basin

b. Stages - Location

West Hill Pool	7.0'
Northbridge, Mass.	6.0'
Woonsocket, R. I.	7.5'

NOTE: Discharge from the reservoir storage is not to be released until contact has been re-established with RRS.



LEGEND
● - PRECIPITATION STA. (USWB)
- RIVER GAGING STA.
- CITY
✚ - PRECIPITATION STA. (C of E)
- STAFF GAGE

BLACKSTONE RIVER BASIN

5 0 5
SCALE IN MILES

NOTE: For complete rainfall and river gaging stations see Plate No. 1.

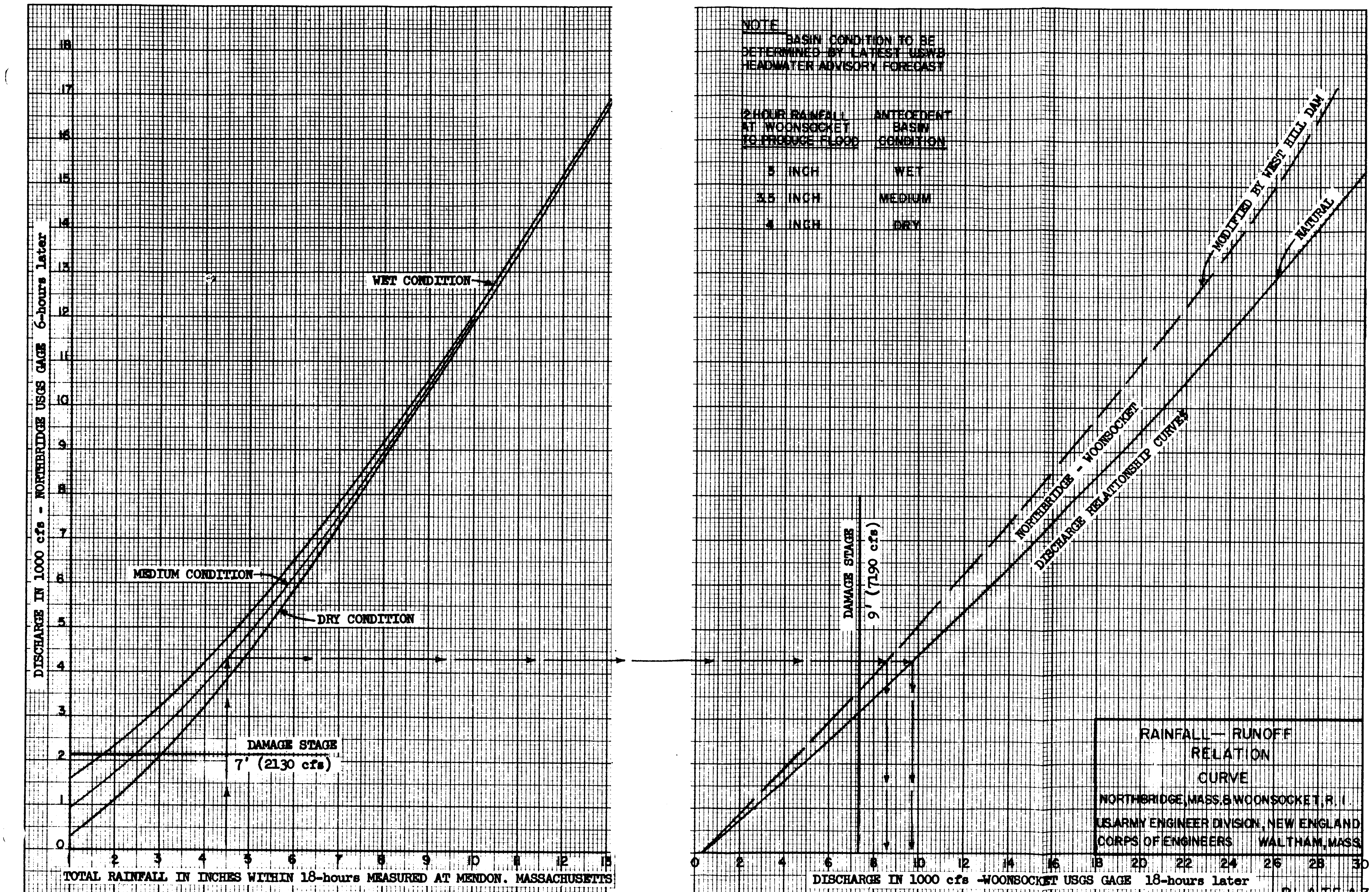
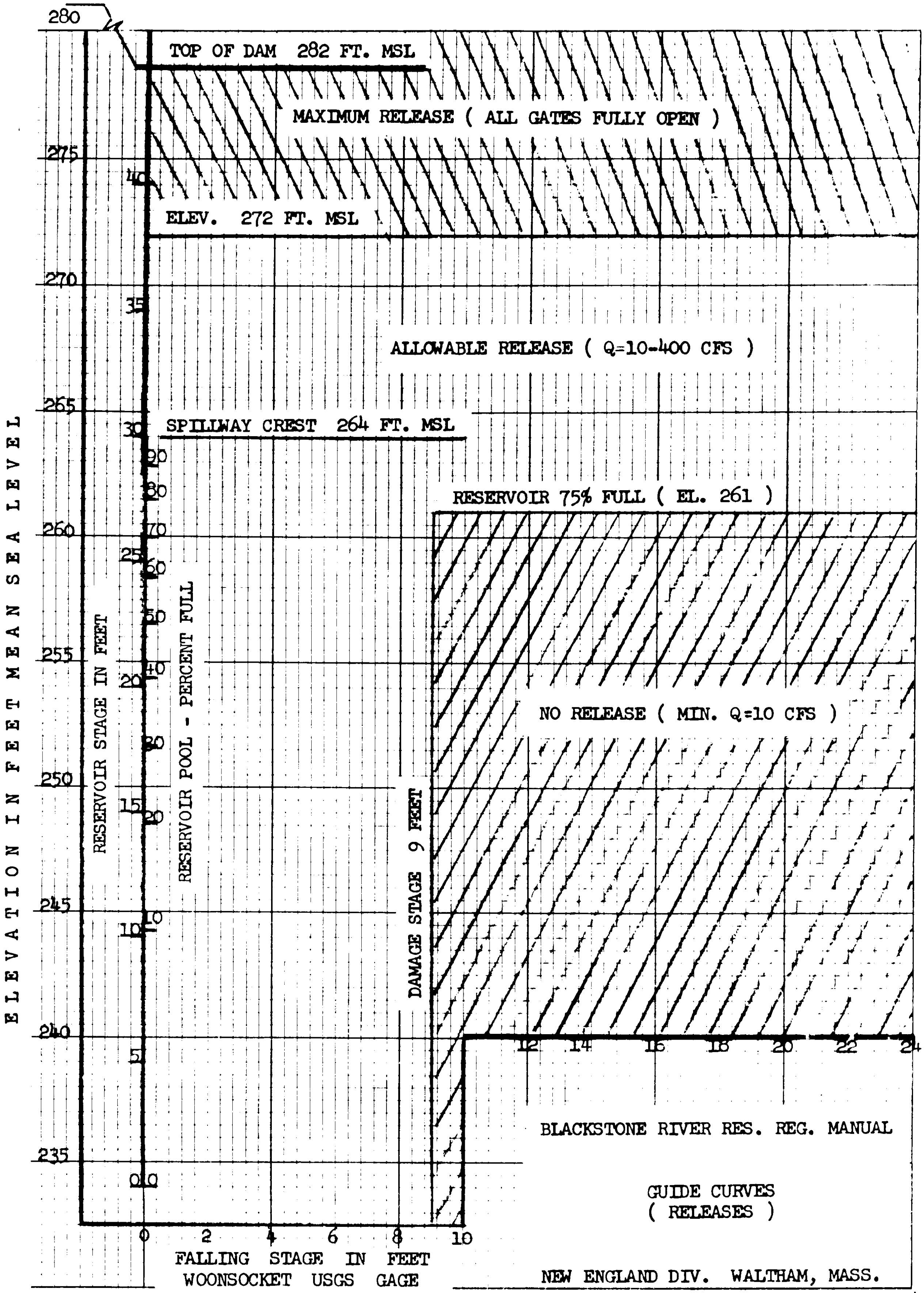

DISCHARGE IN 1000 cfs - NORTHBRIDGE USGS GAGE 6-hours later
TOTAL RAINFALL IN INCHES WITHIN 18-hours MEASURED AT MENDON, MASSACHUSETTS
WET CONDITION
MEDIUM CONDITION
DRY CONDITION
DAMAGE STAGE
7' (2130 cfs)
NOTE
BASIN CONDITION TO BE DETERMINED BY LATEST USWB HEADWATER ADVISORY FORECAST
2 HOUR RAINFALL AT WOONSOCKET TO PRODUCE FLOOD
ANTECEDENT BASIN CONDITION
3 INCH WET
3.5 INCH MEDIUM
4 INCH DRY
MODIFIED BY WEST HILL DAM
NATURAL
NORTHBRIDGE - WOONSOCKET
DISCHARGE RELATIONSHIP CURVES
DAMAGE STAGE
9' (7190 cfs)
DISCHARGE IN 1000 cfs - WOONSOCKET USGS GAGE 18-hours later
RAINFALL— RUNOFF
RELATION
CURVE
NORTHBRIDGE, MASS. & WOONSOCKET, R. I.
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE A-3



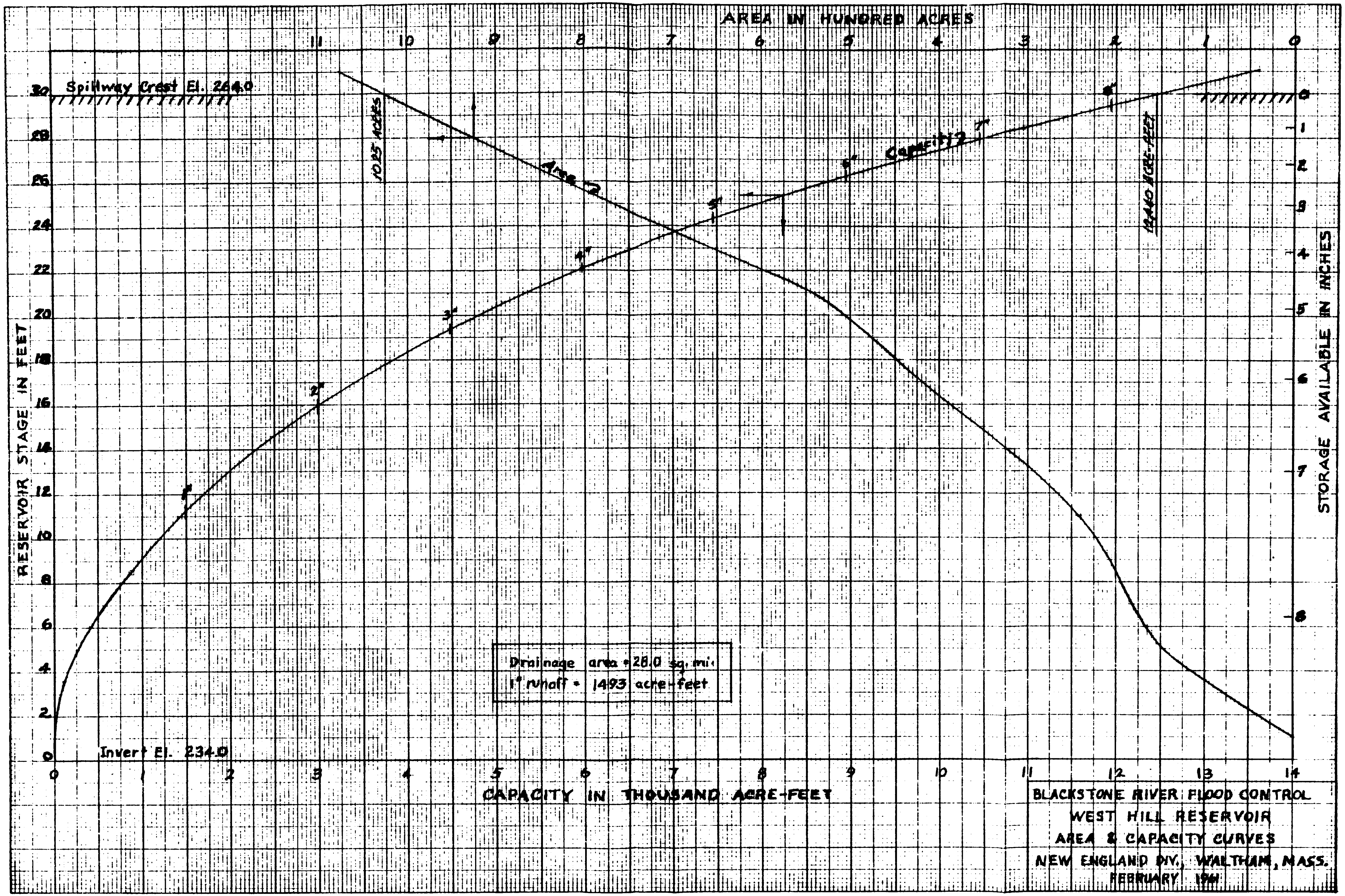
BLACKSTONE RIVER RES. REG. MANUAL

GUIDE CURVES
(RELEASES)

NEW ENGLAND DIV. WALTHAM, MASS.

PLATE A-4

K+E 10 X 10 TO THE INCH 46 0703 7 X 10 INCHES MADE IN U.S.A. KEUFFEL & ESSER CO



AREA IN HUNDRED ACRES
Spillway Crest El. 264.0
1085 ACRES
Area
Capacity
12,440 ACRE-FEET
RESERVOIR STAGE IN FEET
STORAGE AVAILABLE IN INCHES
Drainage area = 28.0 sq. mi.
1" runoff = 1493 acre-feet
Invert El. 234.0
CAPACITY IN THOUSAND ACRE-FEET
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
AREA & CAPACITY CURVES
NEW ENGLAND DIV., WALTHAM, MASS.
FEBRUARY 1941

PLATE NO. A-5

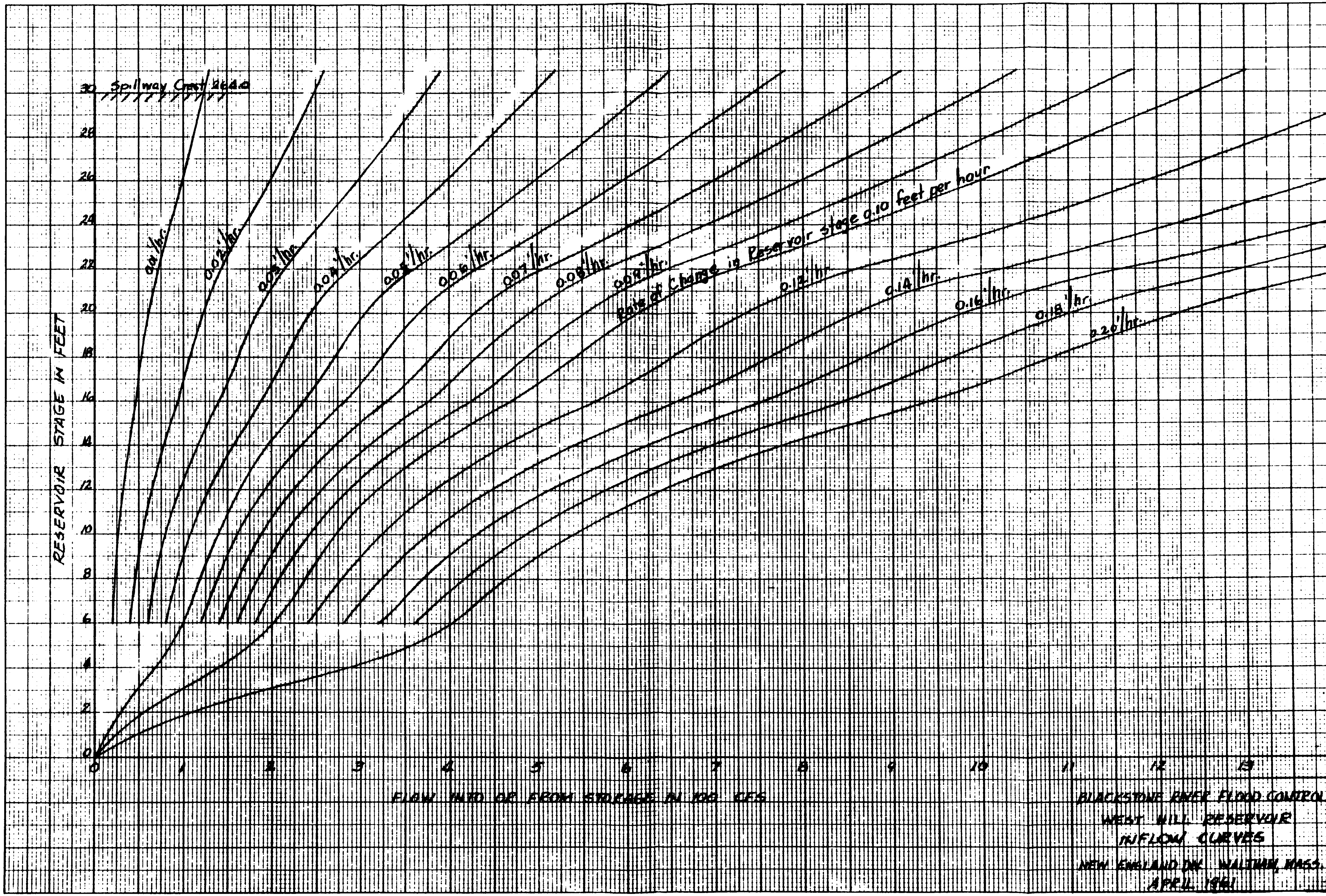

Spillway Crest 264.0
RESERVOIR STAGE IN FEET
FLOW INTO OR FROM STORAGE IN 100 CFS
0.01'/hr.
0.02'/hr.
0.03'/hr.
0.04'/hr.
0.05'/hr.
0.06'/hr.
0.07'/hr.
0.08'/hr.
0.09'/hr.
Rate of Change in Reservoir stage 0.10 feet per hour
0.12'/hr.
0.14'/hr.
0.16'/hr.
0.18'/hr.
0.20'/hr.
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
INFLOW CURVES
NEW ENGLAND DIV. WALTHAM, MASS.
APRIL 1961

PLATE NO. A-6

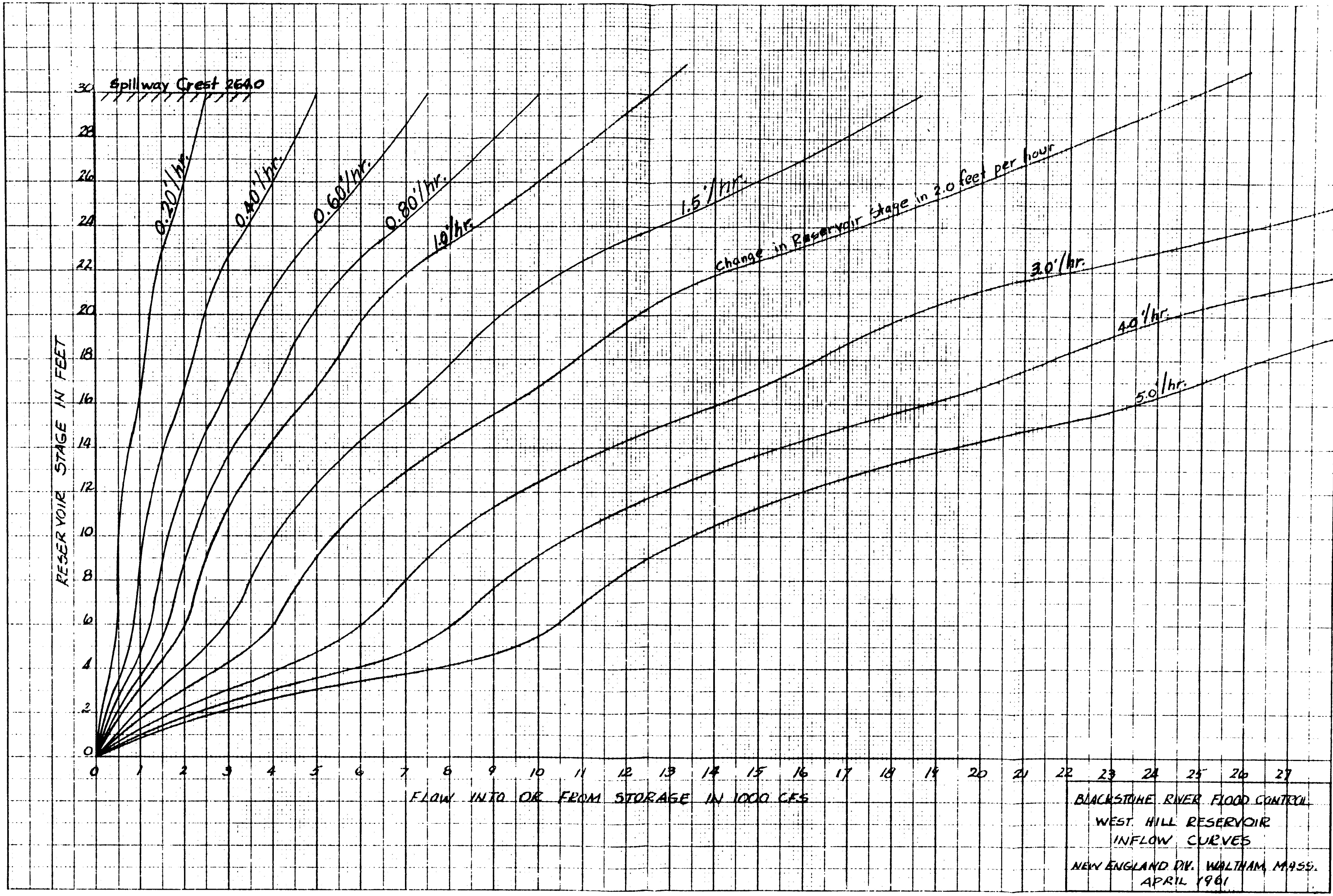
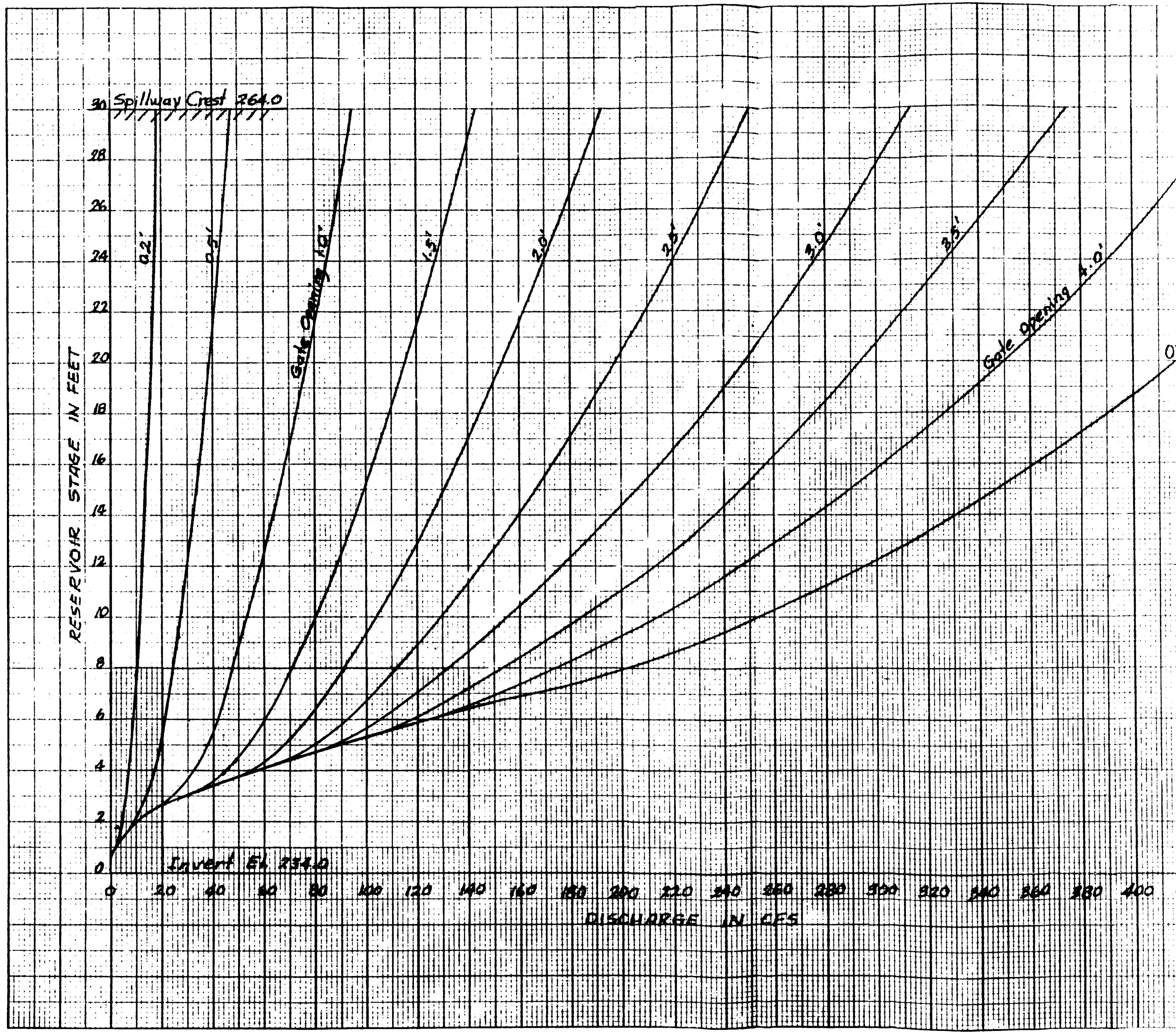

Spillway Crest 264.0
0.20'/hr.
0.40'/hr.
0.60'/hr.
0.80'/hr.
1.0'/hr.
1.5'/hr.
Change in Reservoir Stage in 2.0 feet per hour
3.0'/hr.
4.0'/hr.
5.0'/hr.
RESERVOIR STAGE IN FEET
FLOW INTO OR FROM STORAGE IN 1000 CFS
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
INFLOW CURVES
NEW ENGLAND DIV. WALTHAM, MASS.
APRIL 1961

PLATE NO. A-7



K&E KEUFFEL & ESSER CO. MADE IN U.S.A.

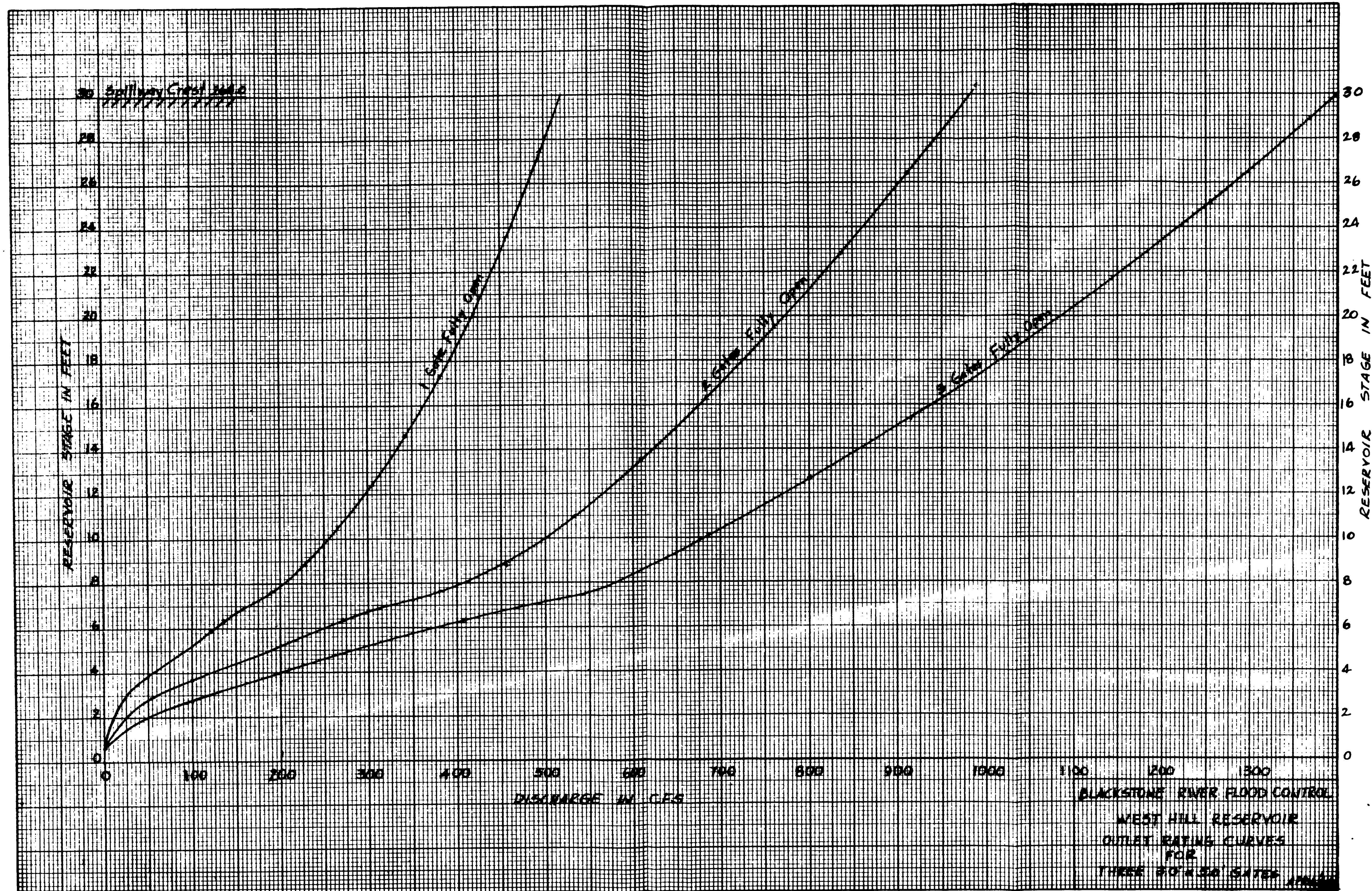
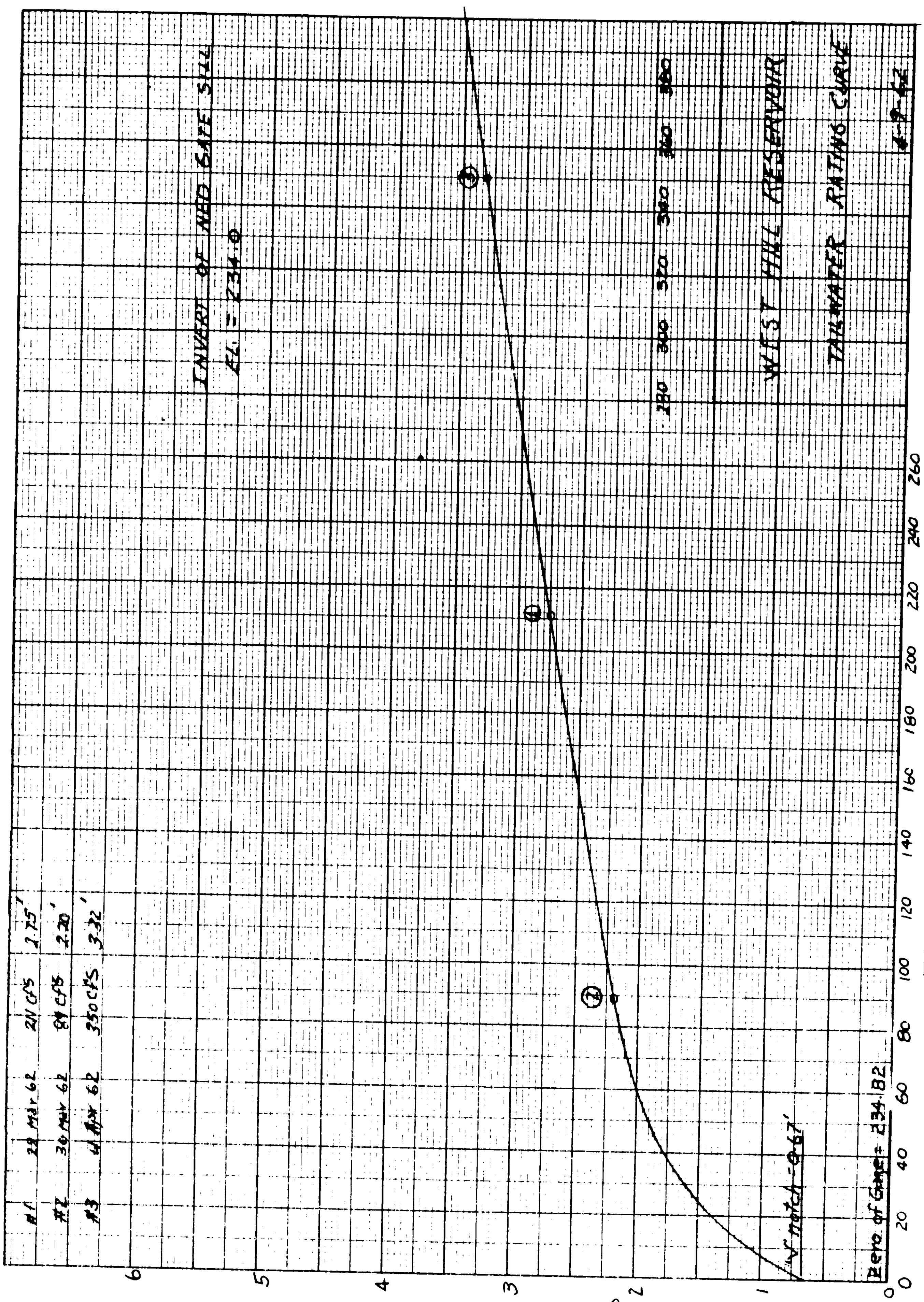
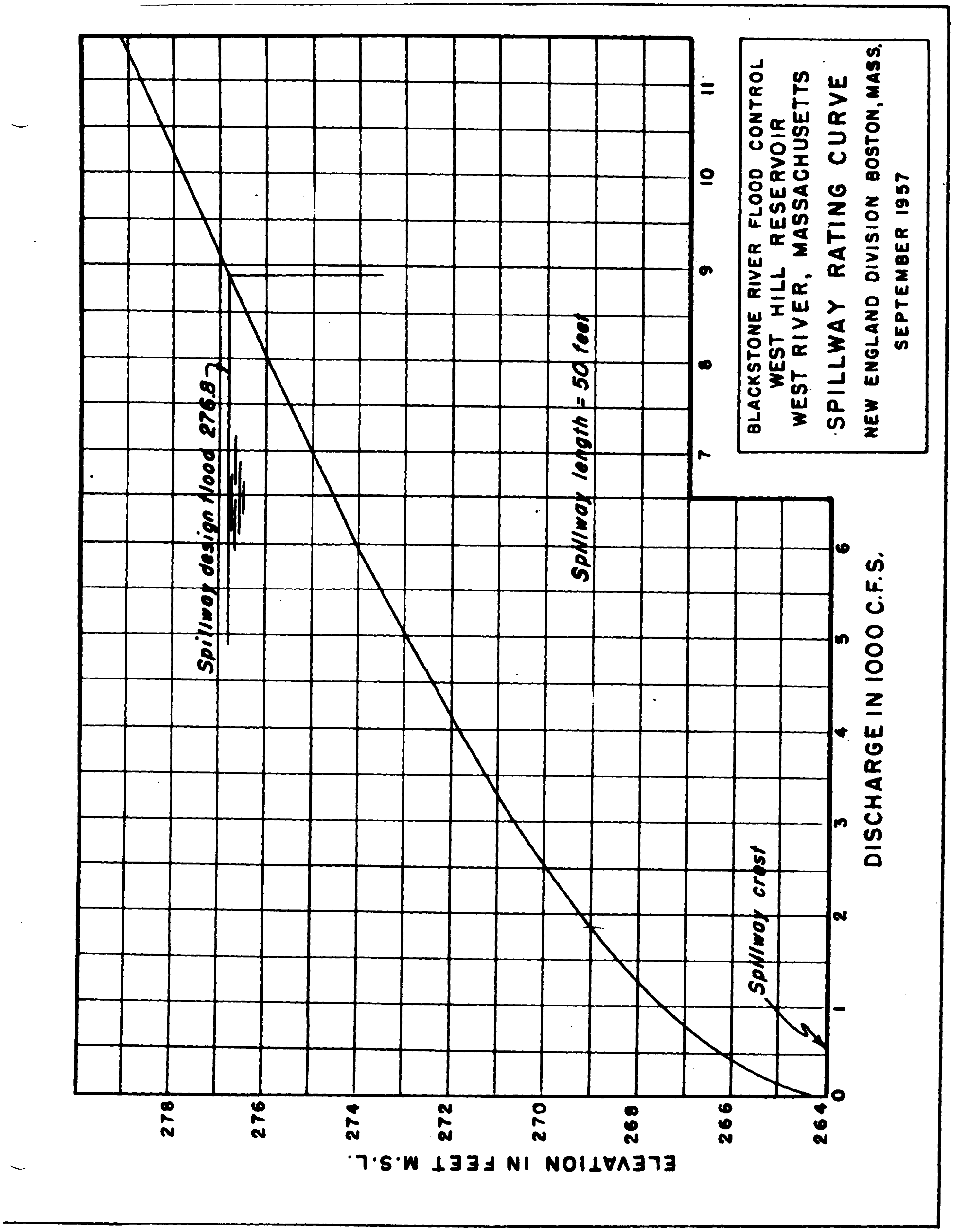

Spillway Crest
1 Gate Fully Open
2 Gates Fully Open
3 Gates Fully Open
RESERVOIR STAGE IN FEET
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
DISCHARGE IN C.F.S.
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
OUTLET RATING CURVES
FOR
THREE 30"x56" GATES

PLATE NO. A-9



INVERT OF NHD GATE SILL
EL = 234.0
WEST HILL RESERVOIR
TAILWATER RATING CURVE
#1 28 Mar 62 211 cfs 2.75'
#2 30 Mar 62 89 cfs 2.20'
#3 4 Apr 62 350 cfs 3.32'
V notch - 0.67'
Zero of Gage = 234.82
Flow in cfs
Stage in feet
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380
0 1 2 3 4 5 6

PLATE NO. A-10


BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
WEST RIVER, MASSACHUSETTS
SPILLWAY RATING CURVE
NEW ENGLAND DIVISION BOSTON, MASS.
SEPTEMBER 1957
Spillway design flood 276.8
Spillway length = 50 feet
Spillway crest
DISCHARGE IN 1000 C.F.S.
ELEVATION IN FEET M.S.L.
0
1
2
3
4
5
6
7
8
9
10
11
264
266
268
270
272
274
276
278

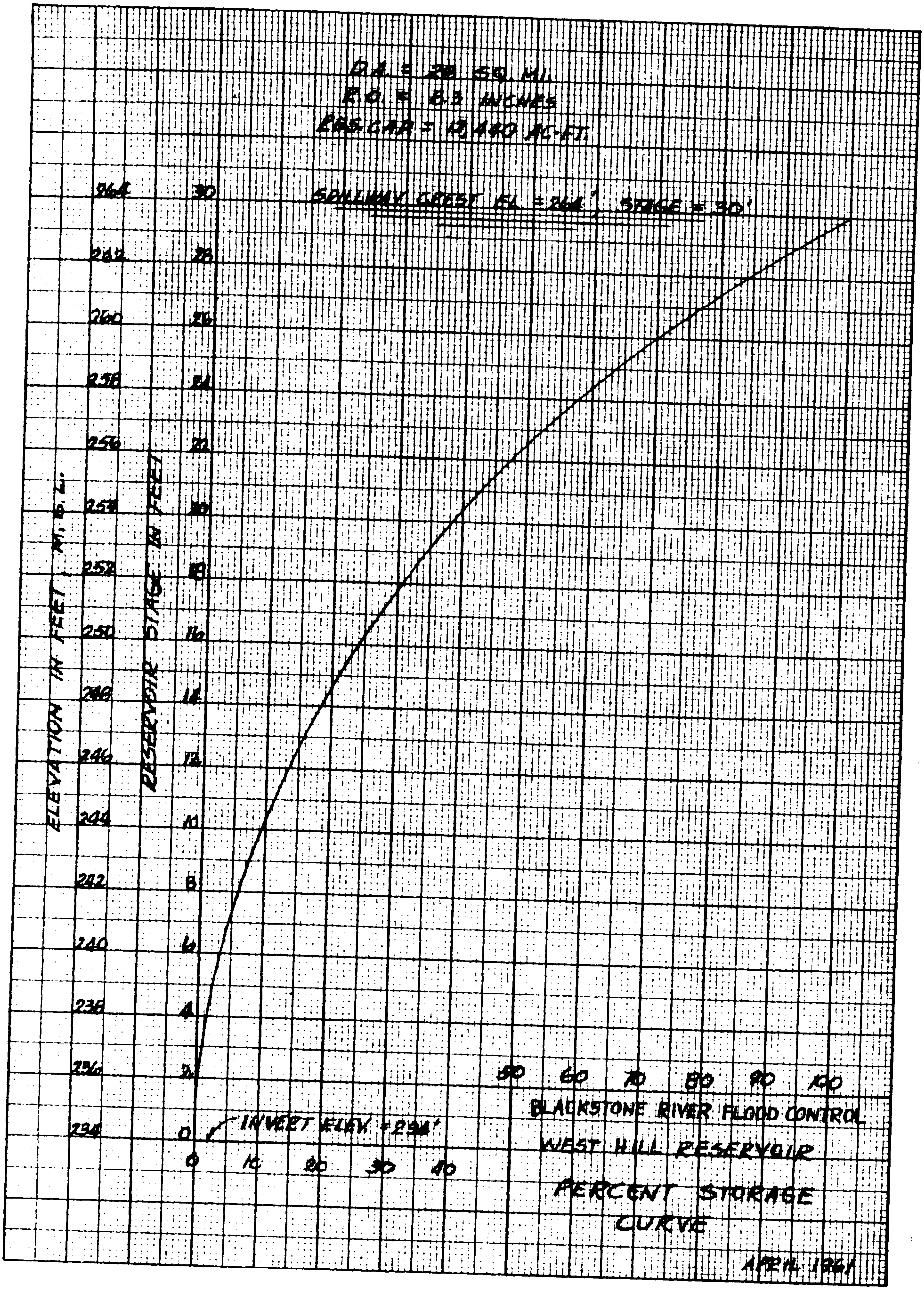
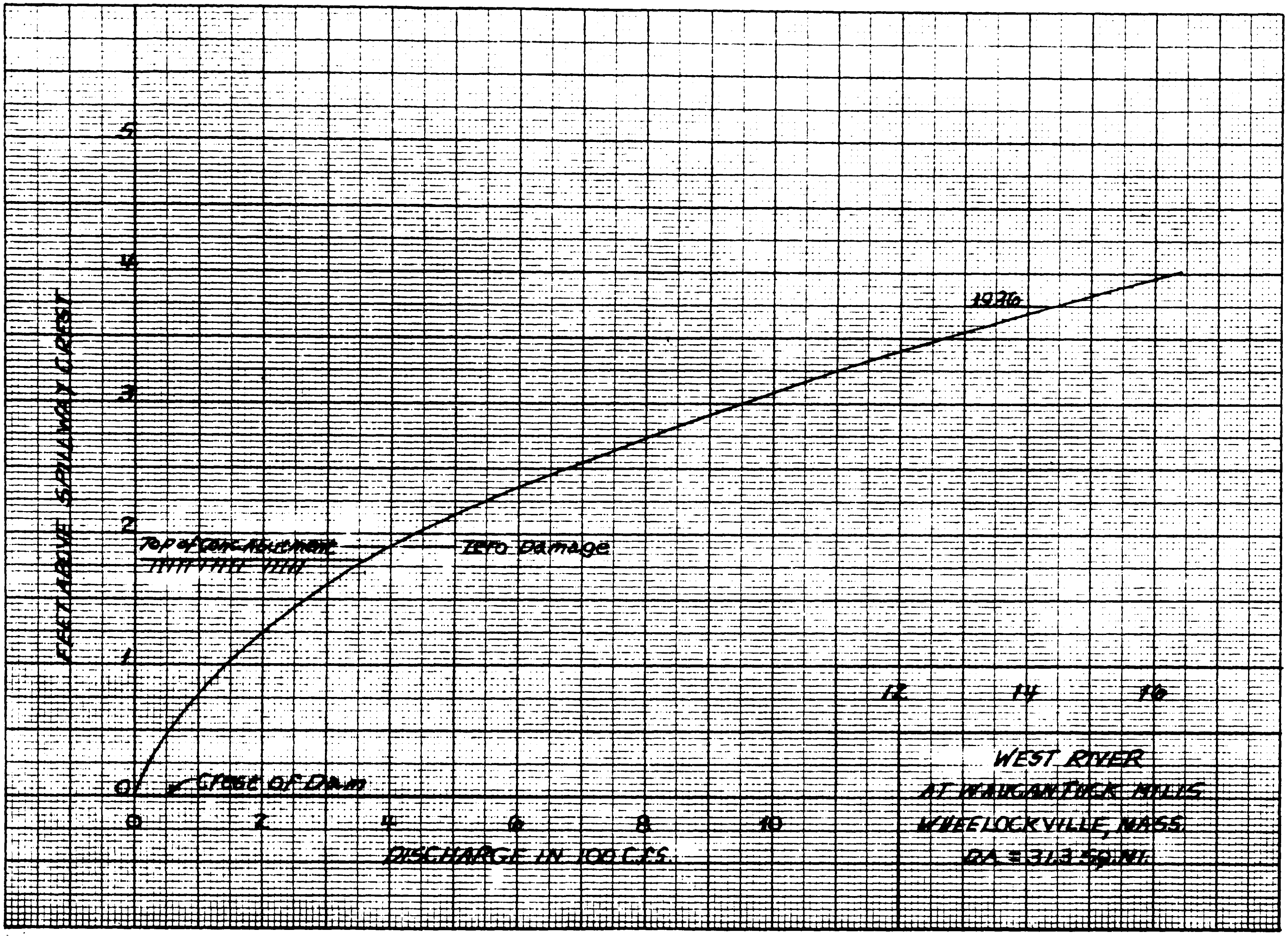

SPILLWAY CREST EL = 264', STAGE = 30'
ELEVATION IN FEET, M.S.L.
RESERVOIR STAGE IN FEET
264
262
260
258
256
254
252
250
248
246
244
242
240
238
236
234
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
INVERT ELEV. = 234'
0
10
20
30
40
50
60
70
80
90
100
BLACKSTONE RIVER FLOOD CONTROL
WEST HILL RESERVOIR
PERCENT STORAGE
CURVE
APRIL 1961

PLATE NO. A-12



FEET ABOVE SPILLWAY CREST
5
4
3
2
1
0
1936
Top of Conc. Abutment
Zero Damage
Crest of Dam
0
2
4
6
8
10
12
14
16
DISCHARGE IN 100 C.F.S.
WEST RIVER
AT WAUCANTUCK MILLS
WHEELOCKVILLE, MASS.
DA = 31.3 SQ.MI.

PLATE NO. A-13

(No. 57)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. | Washington A 12.00 | Field

Rating table for West River below West Hill Dam, near Uxbridge, Mass.
from March, 1962, to , 19 , from , 19 , to , 19 .

Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)
.00			2.00	61	15
.10			.10	76	18
.20			.20	94	20
.30			.30	114	20
.40			.40	134	21
.50			.50	155	22
.60			.60	177	22
.70			.70	199	23
.80			.80	222	23
.95	0.96	From	.90	245	25
1.00	1.60	curve	3.00	270	25
.10	3.50	2.4	.10	295	25
.20	5.9	2.8	.20	320	25
.30	8.7	3.6	.30	345	25
.40	12.3	4.7	.40	370	
.50	17.0	5.5	.50		
.60	22.5	7	.60		
.70	29.5	8.5	.70		
.80	38	10	.80		
.90	48	13	.90		

This table is applicable for open-channel conditions. It is based on 19 discharge measurements made during 1962(1-8), 1963(9-17), 1964(18,19) and is well defined ~~between~~ above 2 cfs. ~~and~~ ~~cfs.~~

Use hundredths throughout

Comp by RAG date 1-16-64
Ckd by RH date 1/20/64
Table No. 1

GPO 868788

PLATE NO. A-14

9-210
(Sept. 1952)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File No. Washington 01A1105.00
Field

Rating table for Blackstone River at Northbridge, Mass.

from Aug. 23, 1957, *to* , 19

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs
1.00			3.00	160	26	5.00	970	60	7.00	2130	50	.00		
.10			.10	186	27	.10	1030		.10	2180	60	.10		
.20			.20	213	28	.20	1090		.20	2240		.20		
.30			.30	241	29	.30	1150		.30	2300		.30		
.40			.40	270	30	.40	1210		.40	2360		.40		
.50			.50	300	30	.50	1270		.50	2420		.50		
.60			.60	330	35	.60	1330		.60	2480		.60		
.70			.70	365	35	.70	1390		.70	2540		.70		
.81	0.42		.80	400	40	.80	1450		.80	2600		.80		
.90	1.15		.90	440		.90	1510		.90	2660		.90		
2.00	3.9		4.00	480	40	6.00	1570		8.00	2720		.00		
.10	8.9		.10	520	45	.10	1630		.10	2780		.10		
.20	16.5		.20	565	45	.20	1690		.20	2840	60	.20		
.30	26.5	12.5	.30	610	50	.30	1750		.30	2900		.30		
.40	39	15	.40	660		.40	1810		.40			.40		
.50	54	17	.50	710		.50	1870	60	.50			.50		
.60	71	20	.60	760		.60	1930	50	.60			.60		
.70	91	22	.70	810		.70	1980		.70			.70		
.80	113	23	.80	860	50	.80	2030		.80			.80		
.90	136	24	.90	910	60	.90	2080	50	.90			.90		

The above table is not applicable for ice or obstructed channel conditions. It is based on 13 discharge measurements made during 1957 (275, 276), 1958 (277-287),

and is well defined between 71 cfs and 2130 cfs.

Extended from 1.90 to 1.81 ft by RAG 11-10-58
Extended from 7.0 to 8.3 ft by GHS 11-13-59

Computed by CGJ

Checked by RAG

Use hundredths throughout

Date 8-29-58

Table no. 17

U. S. GOVERNMENT PRINTING OFFICE 16 -7

PLATE NO. A-15

GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. Field

Rating table for Blackstone River at Woonsocket, R.I. from Dec. 14, 1959 to , 19 from , 19 to , 19

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs
0.00			2.00	296	38	4.00	1580	90	6.00	3580	110	8.00	5920	120	10.00	8540	140	12.00	11400	150
.10			.10	334	41	.10	1670		.10	3690		.10	6040		.10	8680		.10	11550	
.20			.20	375	45	.20	1760		.20	3800		.20	6160	120	.20	8820		.20	11700	
.30			.30	420	50	.30	1850		.30	3910		.30	6280	130	.30	8960		.30	11850	
.40			.40	470	50	.40	1940		.40	4020		.40	6410		.40	9100		.40	12000	
.50			.50	520	55	.50	2030	90	.50	4130	110	.50	6540		.50	9240		.50	12150	
.60			.60	575	55	.60	2120	100	.60	4240	120	.60	6670		.60	9380		.60	12300	
.70			.70	630	60	.70	2220		.70	4360		.70	6800		.70	9520		.70	12450	
.80	26	—	.80	690	60	.80	2320		.80	4480		.80	6930		.80	9660		.80	12600	
.90	30	14	.90	750	65	.90	2420		.90	4600		.90	7060		.90	9800		.90	12750	
1.00	44	16	3.00	815	65	5.00	2520		7.00	4720		9.00	7190		11.00	9940		13.00	12900	
.10	60	18	.10	880	70	.10	2620		.10	4840		.10	7320		.10	10080		.10	13050	
.20	78	19	.20	950	70	.20	2720		.20	4960		.20	7450		.20	10220		.20	13200	
.30	97	22	.30	1020	80	.30	2820	100	.30	5080		.30	7580		.30	10360	140	.30	13350	
.40	119	24	.40	1100		.40	2920	110	.40	5200		.40	7710	130	.40	10500	150	.40	13500	
.50	143	26	.50	1180		.50	3030		.50	5320		.50	7840	140	.50	10650		.50	13650	
.60	169	28	.60	1260		.60	3140		.60	5440		.60	7980		.60	10800		.60	13800	
.70	197	30	.70	1340		.70	3250		.70	5560		.70	8120		.70	10950		.70	13950	
.80	227	33	.80	1420		.80	3360		.80	5680		.80	8260		.80	11100		.80	14100	
.90	260	36	.90	1500	80	.90	3470	110	.90	5800	120	.90	8400	140	.90	11250	150	.90	14250	150

This table is applicable for open channel conditions. It is based on 4 discharge measurements made during 1960 (321-324)

and is well defined between 500 cfs and 15,000 cfs. Comp by LAS date 11/4/60

It is identical with rating 27 above 9.6 ft and with rating 26 above 6.3 ft and below 2.6 ft. Ckd by PEP date 11/10/60

except it is extended below 1.13 ft

Use hundredths throughout

Table No. 28

GPO 863752

PLATE NO. A-16

9-210
(Nov. 19

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. | Field..

Rating table for Branch River at Forestdale, R.I.

from Oct. 1, 1957, to , 19 , from , 19 , to , 19

Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)	Gage height (Feet)	Discharge (Cfs)	Difference (Cfs)
1.00			3.00	198	23	5.00	870	40	7.00	1800	50	9.00	3000	70	.00			.00		
.10			.10	221	24	.10	910		.10	1850		.10	3070	70	.10			.10		
.20			.20	245	26	.20	950		.20	1900		.20	3140	80	.20			.20		
.30			.30	271	28	.30	990	40	.30	1950		.30	3220		.30			.30		
9 .40	5.2	from	.40	299	30	.40	1030	45	.40	2000	50	.40	3300		.40			.40		
.50	5.5	curve	.50	329	31	.50	1075		.50	2050	60	.50	3380		.50			.50		
.60	9.8	5.3	.60	360	31	.60	1120		.60	2110		.60	3460		.60			.60		
.70	15.1	6.4	.70	391	32	.70	1165		.70	2170		.70	3540		.70			.70		
.80	21.5	7.5	.80	423	33	.80	1210		.80	2230		.80	3620		.80			.80		
.90	29	8.5	.90	456	34	.90	1255	45	.90	2290		.90	3700		.90			.90		
.00	37.5	9.5	4.00	490	35	6.00	1300	50	8.00	2350		10.00	3780	80	.00			.00		
.10	47	10	.10	525		.10	1350		.10	2410		.10	3860	90	.10			.10		
.20	57	11	.20	560		.20	1400		.20	2470		.20	3950		.20			.20		
.30	68	14	.30	595	35	.30	1450		.30	2530		.30	4040		.30			.30		
.40	82	16	.40	630	40	.40	1500		.40	2590	60	.40	4130		.40			.40		
.50	98	17	.50	670		.50	1550		.50	2650	70	.50	4220	90	.50			.50		
.60	115	18	.60	710		.60	1600		.60	2720		.60	4310		.60			.60		
.70	133	20	.70	750		.70	1650		.70	2790		.70			.70			.70		
.80	153	22	.80	790		.80	1700		.80	2860		.80			.80			.80		
.90	175	23	.90	830	40	.90	1750	50	.90	2930	70	.90			.90			.90		

This table is applicable for open-channel conditions. It is based on 17 discharge measurements made during 1956 (189, 194, 195, 197, 198), 1957 (199, 201, 202, 205-209), 1958 (210-212, 219), and is well defined between 15 cfs and 4310 cfs. Comp by CGJ date 10-13-58

It is identical with table no. 15 above 3.0 ft.

Use hundredths throughout.

Ckd by FEB date 10-20-58

Table No. 16

U. S. GOVERNMENT PRINTING OFFICE

PLATE NO. A-17

(Nov. 195

GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

File No. Field

Rating table for Kettle Brook at Worcester, Mass.

from Oct. 1, 1961, to Sept. 30, 1962, from Jan. 27, 1964, to , 19

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs
1.00			3.00	53	15	5.00	695	40	7.00	1580	40	9.00	2430	40	11.00	3260	40	.00		
.10			.10	68	17	.10	735	40	.10	1620	45	.10	2470	45	.10	3300		.10		
.20			.20	85	20	.20	775	45	.20	1665	40	.20	2515	40	.20	3340		.20		
.30			.30	105	23	.30	820		.30	1705	45	.30	2555	45	.30	3380		.30		
.40			.40	128	25	.40	865		.40	1750	40	.40	2600	40	.40	3420		.40		
.50			.50	153	27	.50	910		.50	1790	45	.50	2640	45	.50	3460		.50		
.60			.60	180	28	.60	955		.60	1835	40	.60	2685	40	.60	3500		.60		
.70		Draw curve	.70	208	30	.70	1000		.70	1875	45	.70	2725	45	.70	3540		.70		
.80	1.70		.80	238	32	.80	1045		.80	1920	40	.80	2770	40	.80	3580		.80		
.90	2.23		.90	270	35	.90	1090		.90	1960	45	.90	2810	45	.90	3620		.90		
2.00	3.35		4.00	305		6.00	1135		8.00	2005	40	10.00	2855	40	12.00	3660		.00		
.10	4.9	2.0	.10	340	35	.10	1180		.10	2045	45	.10	2895	45	.10	3700		.10		
.20	6.9	2.4	.20	375	40	.20	1225		.20	2090	40	.20	2940	40	.20	3740		.20		
.30	9.3	2.8	.30	415		.30	1270		.30	2130	45	.30	2980		.30	3780		.30		
.40	12.1	3.0	.40	455		.40	1315		.40	2175	40	.40	3020		.40	3820		.40		
.50	15.1	4.2	.50	495		.50	1360		.50	2215	45	.50	3060		.50	3860		.50		
.60	19.3	5.5	.60	535		.60	1405		.60	2260	40	.60	3100		.60	3900		.60		
.70	24.8	7.2	.70	575		.70	1450	45	.70	2300	45	.70	3140		.70	3940	40	.70		
.80	32.0	9.0	.80	615		.80	1495	40	.80	2345	40	.80	3180		.80	3980		.80		
.90	41	12	.90	655	40	.90	1535	45	.90	2385	45	.90	3220	40	.90			.90		

This table is applicable for open-channel conditions. It is based on 16 discharge measurements made during 1961(423-425)
1962(426-437), 1963(428). and is well defined [redacted] [redacted] [redacted]
t is identical with rating 35 below 2.1 ft and above 3.7 ft.
Use hundredths throughout

Comp by RAG date 9-24-62
Ckd by GHS date 9-29-62
Table No. 36

PLATE NO. A-18

Rating table for Quinsigamond River at North Grafton, Mass.

from May 7, 1965, to , 19 , from , 19 , to , 19

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs	Feet	Cfs	Cfs
0.00		From Curve	2.00	81	13	4.00	444	26	.00			.00			.00			.00		
.10			.10	94	14	.10	470	28	.10			.10			.10			.10		
.20			.20	108	15	.20	498	28	.20			.20			.20			.20		
.30	J 0.27		.30	123	15	.30	526	30	.30			.30			.30			.30		
.40	.28		.40	138	16	.40	556	31	.40			.40			.40			.40		
.50	.45		.50	154	16	.50	587	33	.50			.50			.50			.50		
.60	.71		.60	170	17	.60	620	35	.60			.60			.60			.60		
.70	1.40		.70	187	17	.70	655		.70			.70			.70			.70		
.80	2.70		.80	204	18	.80	690		.80			.80			.80			.80		
.90	4.6		.90	222		.90	725	35	.90			.90			.90			.90		
1.00	7.3	3.2	3.00	240	18	5.00	760	40	.00			.00			.00			.00		
.10	10.5	3.5	.10	258	19	.10	800	40	.10			.10			.10			.10		
.20	14	4.5	.20	277		.20	~~840~~		.20			.20			.20			.20		
.30	18.5	6.0	.30	296		.30			.30			.30			.30			.30		
.40	24.5	7.5	.40	315	19	.40			.40			.40			.40			.40		
.50	32	8	.50	334	20	.50			.50			.50			.50			.50		
.60	40	9	.60	354	2[illegible]	.60			.60			.60			.60			.60		
.70	49	10	.70	375	22	.70			.70			.70			.70			.70		
.80	59	10	.80	397	23	.80			.80			.80			.80			.80		
.90	69	12	.90	420	24	.90			.90			.90			.90			.90		

[illegible] 965 (324-332), 1966 [illegible]

[illegible]dent cal with rating 26 above 1.2 ft [illegible] above .6 [illegible]

Extended from 840 to Q 39 ft by LFC 1-19-66, [illegible]

[illegible] KKR date 9-17-65

[illegible] RRG date 10-13-65

Table No. 27

PLATE NO. A-19

APPENDIX B

OPERATIONAL PROCEDURES AND MAINTENANCE

OF

HYDROLOGIC EQUIPMENT

APPENDIX B

OPERATIONAL PROCEDURES AND MAINTENANCE
OF HYDROLOGIC EQUIPMENT

TABLE OF CONTENTS

- Conduct Corps review.

APPENDIX B

OPERATIONAL PROCEDURES AND MAINTENANCE OF HYDROLOGIC EQUIPMENT

1. PRECIPITATION GAGE

An unofficial plastic wedge-shaped fence gage is installed at West Hill Dam. For ease of observation the gage is located at the operator's house and serves as a supplement to the standard USWB rainfall stations at Northbridge and Mendon, Massachusetts and Woonsocket, Rhode Island.

2. RESERVOIR STAGE RECORDER

The automatic water level recorder at West Hill traces the water level in the reservoir at all times. The water-stage recorder is operated by a float. The recording instrument should be checked each morning to assure that the clock is keeping correct time and the pen is tracing properly. Any discrepancies in the record as evidenced by the pen time or gage height should be noted on the chart and the instrument reset. During periods of reservoir storage, the outside tile or staff gage should be read to check tape readings and chart record. Should the records become inoperable, RRS should be notified and arrangements will be made to put the recorder back into operation. The chart record should be changed the first working day of each month. At the beginning and end of each monthly chart, the following information should be noted in ink:

Outside (tile) gage reading
Pen gate height reading
Watch time
Pen time
Date and name of dam

New charts for monthly recorders should be obtained from the NED warehouse.

3. TAILWATER GAGING STATION

A tailwater gaging station is located downstream of the dam to provide a continuous official record of discharge from the dam. The gaging station is equipped with a remote recording system which transmits data to the West Hill gatehouse. It is essential the equipment be checked frequently to assure a continuous record. Tailwater gage readings included in the routine radio and telephone reports to the RRS on Fridays are used for calibration of the gages and as a ready reference of basin runoff conditions at the time of observation. If inspection of the gage indicates a need for repair, RRS should be notified immediately and arrangements will be made with the USGS to have the equipment repaired.

4. TELEPHONE TRANSMITTER (TELEMARK)

A telephone transmitter (telemark) is in operation on the Blackstone River at Northbridge, Massachusetts to obtain river stages to aid in regulating West Hill Dam. Presently telemarks are the most satisfactory method of river stage reporting, especially where it is essential to have 24-hour coverage of the index stations. Should the telemark become inoperative the dam operator should visit the USGS gage to ascertain the source of the difficulty. If the trouble cannot be determined at the gage, the telephone company should be requested to check out their circuits. The operator should be at the gage when the telephone company inspects their system. If the telemark still cannot be made operative, the RRS should be notified and NED or USGS personnel will inspect the gaging station.

Batteries for the Stevens telemark at Northbridge, Massachusetts will be furnished and installed by the FCDO.

5. SNOW SAMPLING SET

A snow sampling set has been assigned to the FCDO. Procedures for obtaining snow survey data should follow instructions set forth in Snow Survey Sampling Guide, Department of Agriculture Handbook 169. If given proper care, the only maintenance required would be occasional replacement of worn-out cutterheads.